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FOR THE LANDSAT-D SYSTEM, REVISION C (NASA)

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GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

GSFC 430-D-100C
March 1981
Superseding
GSFC 430-D-100B
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FOR THE
LANDSAT-D SYSTEM

GODDARD SPACE FLIGHT CENTER
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GSFC SPECIFICATION
FOR THE
LANDSAT-D SYSTEM

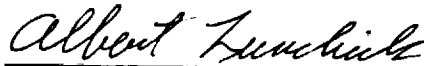
REVISION C

MARCH 1981

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GODDARD SPACE FLIGHT CENTER
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**SPECIFICATION FOR THE
LANDSAT-D SYSTEM**

The mission system desired by the Government must, as a minimum, meet the specifications as stated herein. ■

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LIST OF DEFINITIONS

Data Management System

The ground based system for processing NASA instrument data.

Domsat System

The two-way communications system linking the Operations Control Center and Data Management System with the TDRSS ground station.

Flight Segment

The Flight Segment is the on-orbit segment of the Landsat-D system exclusive of any launch subsystems. The Flight Segment consists of two subsystems, the Instrument Module and the Multimission Modular Spacecraft.

Flight Segment System

The Flight Segment System is defined to include all subsystems required for prelaunch integration, test, transportation, and storage of the Flight Segment; for launch of the Flight Segment; and the Flight Segment itself.

Foreign Users

Users, other than the U.S., receiving instrument data directly from the Landsat-D Flight Segment.

Ground Segment

The Ground Segment is the ground portion of the Landsat-D system. The Ground Segment consists of the Operations Control Center, the Data Management System, the Landsat-D Assessment System and the Transportable Ground Station.

Image

An image is the representation produced by either Landsat-D instrument of approximately 185km by 185km of the earth's surface in one band.

Instruments

The Thematic Mapper and the Multispectral Scanner.

Instrument Module

The D and D' Flight Segment Instrument Modules consists of the TM and MSS instruments. Each Instrument Module has Mission Unique Subsystems necessary to supplement the Multimission Modular Spacecraft. The term Instrument Module includes both electrical and mechanical subsystems and is composed of both Government Furnished Equipment and contractor provided equipment. The Instrument Module and the Multimission Modular Spacecraft comprise the Flight Segment.

Mission Options

Mission Options are Standard Government Furnished Equipment designed to be mounted in the Multimission Modular Spacecraft and which may be chosen to suit the needs of the Flight Segment. Mission Options are defined to be located in the Multimission Modular Spacecraft.

Mission Unique Subsystems

Mission Unique Subsystems are those subsystems which are necessary to supplement the functions of the Multimission Modular Spacecraft. Mission unique Subsystems are defined to be located in the Instrument Module and may be either Government Furnished Equipment or contractor supplied equipment.

Multimission Modular
Spacecraft

The Multimission Modular Spacecraft is Government Furnished Equipment and is made up of standard modules and structures to provide basic power, attitude control, and data handling functions to the Flight Segment. The Multimission Modular Spacecraft may be configured in a number of ways by choosing particular sets of standard Mission Options. The Multimission Modular Spacecraft and the Instrument Module comprise the Flight Segment.

Scene -

A scene consists of each of the images in different bands produced by either of the Landsat-D or D' instruments for a given approximate 185km x 185km segment of the earth's surface.

Tracking and Data Relay
Satellite System (TDRSS)

The two-way NASA communications system including the satellites and ground station.

ACRONYMS AND ABBREVIATIONS

ACS	Attitude Control Subsystem
ADP	Automated Data Processing
ADS	Angular Displacement Sensor
Ah	Ampere-hour
APL	Approved Parts List
BCU	Bus Coupling Unit
BER	Bit-Error Rate
BIL	Band Interleaved by Line
bpi	Bits per inch
BSQ	Band Sequential
CAL	Configured Articles List
CCB	Configuration Control Board
CCT	Computer-compatible tape
C&DH	Communications and Data Handling
CDR	Conceptual Design Review
CI	Configuration Item
CM	Configuration Management
CRT	Cathode-ray tube
dBi	Antenna gain in decibels referenced on an isotropic antenna
dBm	Power in decibels, referenced to 1 milliwatt
DDR	Detailed Design Review
DMS	Data Management System
Domsat	Domestic Communications Satellite
EDC	EROS Data Center
EMI/EMC	Electromagnetic interference and compatibility
FM	Flight Model
FMEA	Failure-Mode and Effects Analysis
FSS	Flight Support System
GAO	Government Accounting Office
GIA	Government Inspection Agency
GCP	Geodetic control point
GFE	Government-furnished equipment
GFP	Government-furnished Property
GMT	Greenwich Mean Time
GPS	Global Positioning System
GSA	General Services Administration
GSE	Ground-Support Equipment
GSFC	Goddard Space Flight Center
GSTDN	Ground Space Tracking Data Network
HDT	High-density Magnetic Tape
HDDT	High-density Data Tape
Hz	Hertz
ICD	Interface Control Document
ID	Identification
IPF	Image Processing Facility
IR	Infrared
ISD	Interface Specification Document

JSC	Johnson Space Center
km	Kilometer
KSA	Ku-Band Single Access
LAS	Landsat-D Assessment System
m	Meter
MCC	Mission Control Center
MEM	Module Exchange Mechanism
MHz	Megahertz
mm	Millimeter
MMS	Multimission Modular Spacecraft
MRB	Material Review Board
MSFC	Marshall Space Flight Center
MSS	Multispectral Scanner
MTF	Modulation Transfer Function
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NASTRAN	NASA Structural Analysis (Program)
NDS	Navigation Data Satellites
NOAA	National Oceanic and Atmospheric Administration
NRZ-M	Non-return to Zero - Mark
NSPAR	Nonstandard Parts Approval Request
NTTF	Network Test and Training Facility
OBC	Onboard Computer
OCC	Operations Control Center
OSCD	Operations Support Computing Facility (GSFC)
PAPL	Program Authorized Parts List
PCD	Payload Correction Data
PN	Pseudonoise
PPL	Preferred Parts List
PRN	Pseudo-random Noise
PS	Polar Stereographic
PSK	Phase-shift Keyed
RF	Radio Frequency
RH	Relative Humidity
RIU	Remote Interface Unit
rms	Root Mean Square
RMS	Remote Manipulator System
R/PA	Receiver/Processor Assembly
R&PA	Reliability and Product Assurance
RT	Real Time
SAD	Solar-array Drive
SC&CU	Signal Conditioning and Control Unit
SIRD	Support Instrumentation Requirements Document
SMA	S-band Multiple Access
SOM	Space Oblique Mercator
SSA	S-band Single Access
STACC	Standard Telemetry and Command Components
STDN	Space Tracking and Data Network
STINT	STACC Interface Unit
STR	Standard Tape Recorder
STS	Space Transportation system

TCG	Time-code Generator
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TGS	Transportable Ground Station
TLM	Telemetry
TM	Thematic Mapper
USB	Unified S-band
UTM	Universal Transverse Mercator
VAFB	Vandenberg Air Force Base
WBS	Work-Breakdown Structure
WRS	World Reference System
WTR	Western Test Range

1.0 SCOPE

This specification establishes the requirements for the performance design, qualification, and acceptance testing of the Landsat-D System which includes the on-orbit Flight Segment System, the Operations Control Center (OCC), the Data Management System (DMS), and the Landsat Assessment System (LAS). In addition, this document specified requirements for major Landsat-D interfaces, documentation, configuration management, flight assurance, Government Furnished Equipment, and other contractual responsibilities. Unless noted, these specifications pertain to both Landsat-D and D prime systems.

1.1 PROJECT OBJECTIVES

The major project objectives of the Landsat-D Project are to:

- a. Provide definite assessments of the capability of the TM to provide improved information for Earth resources management.
- b. Provide system level feasibility demonstrations that will aid federal agencies in any further decisions on the need for an operational system and define the essential features of such a system and its probable costs.
- c. Continue foreign support and investment in the program.

2.0 APPLICABLE DOCUMENTS

The following documents form a part of this specification to the extent specified herein. In the event of conflict between documents referenced here and the requirements in this specification, the requirements of this specification shall supersede. In the event of conflict between documents referenced here and lower tier references to documents referenced here, the former supersede.

2.1 SPECIFICATIONS

2.1.1 Landsat Specification

2.1.1.1 DELETED

2.1.2 Multimission Modular Spacecraft Specifications

- | | | |
|---------|----------|--|
| 2.1.2.1 | S-700-10 | Multimission Modular Spacecraft System Specification, NASA/GSFC, May 1977. |
| 2.1.2.2 | S-700-11 | Multimission Modular Spacecraft External Interface Control and User Guide, NASA/GSFC, April 1978. |
| 2.1.2.3 | S-700-12 | Multimission Modular spacecraft Thermal System Specification, NASA/GSFC, April 1977, Rev. A. |
| 2.1.2.4 | S-700-13 | Mechanical System Specification for the Multimission Modular Spacecraft (MMS), NASA/GSFC, May 1977. |
| 2.1.2.5 | S-700-14 | Multimission Modular Spacecraft (MMS) Electrical Systems Specification, NASA/GSFC, September 1978. |
| 2.1.2.6 | S-700-15 | Multimission Modular Spacecraft (MMS) Communications and Data Handling (C&DH) System Specification, NASA/GSFC, October 1978. |
| 2.1.2.7 | S-700-16 | Specification for Multimission Modular spacecraft (MMS) Modular Power Subsystem, NASA/GSFC, May 1976. |

2.1.2.8	S-700-17 Including changes thru 236-M dated 5/1/80	Specification for Multimission Modular Spacecraft (MMS) Attitude Control Subsystem, NASA/GSFC, April 1976.
2.1.2.9	S-700-18	Multimission Modular Spacecraft (MMS) Subsystem Module Environmental Test Specification, NASA/GSFC, April 1976.
2.1.2.10		Deleted
2.1.2.11	S-700-54	Standard Telemetry and Command Components Remote Interface Unit (RIU) User's Guide, NASA/GSFC, September 1979, Rev. A.
2.1.2.12	S-700-56	Multimission Modular Spacecraft (MMS) Onboard Computer (OBC) Flight Executive Technical Description, Revision B, February 1980.
2.1.2.13	S-700-41	Multimission Modular Spacecraft (MMS) Signal Conditioning and Control Unit Specification, NASA/GSFC, March 1977
2.1.2.14	S-700-19/1	Multimission Modular Spacecraft (MMS) PM-1A Propulsion Module Specification, NASA/GSFC, March 1980.
2.1.2.15	S-700-100	Ground Support System, NASA/GSFC, May 1977.
2.1.2.16	S-700-41/2	Multimission Modular Spacecraft (MMS) Signal Conditioning and Control Unit Interfaces Control Requirement Document for the Landsat-D Mission, NASA/GSFC July 1980, Revision A
2.1.2.17	S-700-14/1	MMS Electrical System Interface Control Requirements Document (ICRD) for the Landsat-D Spacecraft, Rev A December 1980.

2.1.3 Thematic Mapper Specifications

2.1.3.1 GSFC 400.8- GSFC Specification: Thematic
D-201 Rev. Mapper Interface Control
B Document, NASA/GSFC, April 1978

2.1.3.2 GSFC 400.8- GSFC Specification: Thematic
D-210 Rev. Mapper System and Associated Test
B Equipment, NASA/GSFC,
April 1978

2.1.4 Multispectral Scanner Specifications

2.1.4.1 GSFC 430-D- GSFC Specification for
205 Rev. B Multispectral Scanner System,
C-1, Sept. May 1978
18, 1978

2.1.4.2 S-430-D-340 GSFC Specification for
Revision A Environmental and System Test
Specification for the
Multispectral Scanner, May 1978

2.1.4.3 Deleted

2.1.4.4 Drawing No. Interface Control
3617120-400 Drawing--Multispectral Scanner
June 16, 1980

2.1.4.5 Drawing No. Interface Control
3617140-400 Drawing--Multiplexer January 29,
1979

2.1.4.6 Deleted

2.1.5 Tracking and Data Relay Satellite System
Specifications

2.1.5.1 S-805-1 Performance Specification for
Revision A Services via the Tracking and
Data Relay Satellite System,
GSFC, December 1979.

2.1.5.2 JPL STD 336- Design Requirement, NASA Standard
M04-TD (W/ TDRSS User Transponder, Jet
Rev/ E. Propulsion Laboratory.
April 28,
1977

- 2.1.6 Test Specification
- 2.1.6.1 GETS (ELV)-1 General Environmental Test
W/ C-1, Specification for Spacecraft and
11/15/77; Components (Expendable Launch
C-2, Vehicles), NASA/GSFC, October
12/22/77 1976.
- 2.1.7 Data Management System Documentation
- 2.1.7.1 S-812.3-9 High Data Rate Recorders;
W/Mod. 4, February 1976; latest revision,
Oct. 3, November 1976.
1977
- 2.1.7.2 None Specification, High Density
Digital Recorder, and Addendum to
Specification.
- 2.1.7.3 None Performance Requirements for a
High Resolution Film Recorder,
Rev. A.
- 2.1.7.4 IPF-ICD-201, Partially Processed Multispectral
W/ Rev. 8, Scanner High Density Tape
10/3/80 (HDT-AM/AMC), April 1977.
- 2.1.7.5 None IPF High Density Tape Recording
System, Revision 2, Martin, July
1976.
- 2.1.7.6 None Performance Requirements for a
Quality Assurance film recorder.
"Note on Item 11 of this
document. 40 lines pairs per mm
should be 30 lines pairs per mm.
- 2.1.8 Space Transportation System Documentation
- 2.1.8.1 JSC-077700 Space Shuttle System Payload
Accommodations, Vol. XIV, Rev. F,
NASA/JSC, September 22, 1978.
- 2.1.8.2 NHB 1700.7A Safety Policy and Requirements
for Payloads Using the National
Space Transportation System,
NASA/HQ, Office of Space Flight,
December 1980.
- 2.1.8.3 JSC 11123 Space Transportation System
Payload Safety Guidelines
Handbook, July 1976.

2.1.8.4	K-STSM-14-1	Launch Site Accommodations Handbook for STS Payloads, Rev. A, NASA/KSC, March 1980.
2.1.8.5	JSC-13830	Implementation Procedure for STS Payload System Safety Requirements, May 1979.
2.1.8.6	Deleted	
2.1.8.7	Deleted	
2.1.8.8	Deleted	
2.1.8.9	None	Estimated STS Landing Loads for the Landsat-D/MMS Spacecraft, January 3, 1979.
2.1.8.10	408-2112-0004	Multimission Modular Spacecraft Flight Support System User Guide March 1980
2.1.9	<u>Global Positioning System Documentation</u>	
2.1.9.1	Deleted	
2.1.9.2	APL Spec. 7250-9000	Specification for GPS PAC Receiver/Processor Assembly December 21, 1976
2.1.9.3	APL-7250-9003	Interface Control Document (ICD) for GPS PAC Receiver/Processor Assembly (R/PA). September 4, 1979 through Interface Revision Notices F001 thru F033.
2.1.10	<u>Standard Tape Recorder Documentation</u>	
2.1.10.1	73-15038, Rev. F.	4.5×10^8 Bit Standard Spacecraft Tape Recorder Specification, NASA/GSFC, August 1979.
2.1.10.2	GSFC 435-D-105	Landsat-D Unique Performance Requirements for the 10^8 Standard Tape Recorders, NASA/GSFC, October 1979.
2.1.10.3	Deleted	

2.2	STANDARDS, HANDBOOKS AND DRAWINGS	
2.2.1	<u>NASA</u>	
2.2.1.1	PPL-14	GSFC Preferred Parts List. June 1978
2.2.1.2	NHB 5300.4 (1A)	Reliability Program Provisions for Astronautical and Space System Contractors, April 1970.
2.2.1.3	X-601-77-70	Radiation Environment for Landsat-D, March 1977.
2.2.1.4		Intentionally left blank
2.2.1.5	NHB 5300.4 (1B)	Quality Program Provisions for Aeronautical and Space System Contractors. April 1969
2.2.1.6	S-250-P-1C	Contractor-Prepared Monthly, Periodic, and Final Reports. March 1972
2.2.1.7	S-253-P-4A	Motion Picture and Still Documentary Photography by Contractors. August 1971
2.2.1.8	SP-7013	NASA Publications Manual, 1974.
2.2.1.9		Deleted
2.2.1.10	S-311-80	Parts Program Requirements for GSFC Spaceflight Projects, NASA/GSFC. October 7, 1979
2.2.1.11	MIL-STD-975A (NASA)	Standard Parts Lists for Flight and Mission-Essential Ground Support Equipment, NASA, August 1977.
2.2.1.12	MTR-313-003	An Evaluation of Liquid and Grease Lubricants for Spacecraft Applications, NASA/GSFC, December 1976.
2.2.1.13	NRP 1014	Outgassing Data compilation of Spacecraft Materials, NASA, January 1978.
2.2.1.14	NHB 5300.4 (3A-1)	Requirements for Soldered Electrical Connections, NASA, December 1976.

2.2.1.15	RS-422	Electrical Characteristics of Balanced Voltage Digital Interface Circuits, Electronic Industries Association Standards, April 1975.
2.2.1.16	FSEC Dwg. E624-1101- 000	Transition Adapter Assy, Triangular, MMS. April 26, 1979
2.2.2	<u>Other</u>	
2.2.2.1	DAC 61687D	Delta Spacecraft Design Restraints, McDonnell Douglas Astronautics Co., July 1980.
2.2.2.2	AFR 71-4	Preparation of Hazardous Material for Military Air Shipment. March 27, 1976 as Amended by Change 3 dated June 29, 1979.
2.2.2.3	SAMTECM 127-1	Air Force Western Test Range Safety Manual, Vol. I, July 1973.
2.2.2.4	DOD-STD-480A	Configuration Control Engineering Changes, Deviations, and Waivers. April 12, 1978
2.2.2.5		Deleted
2.2.2.6	None	Manual of Regulations and Procedures, RF management, Executive Office of the President, Paragraph 8.2.36 (one page tabulation). Sept 1976
2.2.2.7	NHB-1700.1 (VI)	Basic Safety Requirements. May 1979
2.2.2.8	GMI 1700.2B	GSFC Health and Safety Protection Program. July 19, 1979
2.2.2.9	SP-386	Outlook for Space, NASA/HQ, January 1976.
2.2.2.10	MIL-STD-483	Configuration Management Procedures for Systems, Equipment, Munitions, and Computer Programs. December 31, 1970
2.2.2.11	Deleted	

2.2.2.12	STDN No. 101.2	Tracking and Data Relay Satellite (TDRSS) User's Guide, Revision 4, dated January 1980, GSFC
2.2.2.13	MM-4311-01	Interface Control Document between the Goddard Space Flight Center Project Operations Control Center and the Network Control Center, December 19, 1979.

3.0 LANDSAT-D SYSTEM REQUIREMENTS

3.1 LANDSAT-D SYSTEM FUNCTION

The Landsat-D System shall consist of six major elements

- o Landsat-D Flight Segment
- o Landsat-D' Flight Segment
- o Operations Control Center (OCC)
- o Data Management System (DMS)
- o Landsat-D Assessment System (LAS)
- o Transportable Ground Station (TGS)

The System shall produce world-wide scenes of the Earth's surface from a nominal sun-synchronous orbit of 705.3 Km, 98.2° inclination, and a 9:45 AM, mean solar time \pm 15 minutes, sun angle at the descending node. These images shall be obtained from an on-orbit Multispectral Scanner (MSS) instrument and a Thematic Mapper (TM) instrument. The Landsat-D/D' orbit shall be defined as requiring a launch window of 9:38 AM - 0 + 15 min. at time of first descending node with subsequent orbit station-keeping required to maintain a 9:45 AM, mean solar time at the descending node. The orbit shall be such as to produce 233 orbits per ground trace repeat cycle and 14 9/16 orbits/24 hr. day. The Landsat-D flight segment will be launched first and the Landsat D' flight segment will be available for launch 1 year later. The World Reference System will be established by the Landsat-D mission. Landsat-D', when launched, would be placed in the same World Reference System and offset 8 days from the Landsat-D coverage cycle. The DMS shall be the central processing facility for image data received by NASA; foreign users will also receive image data but will provide their own processing facilities. The Flight Segment shall be capable of producing at least the scene rates defined in Table 3.1-1; the DMS shall be capable of receiving and processing the MSS scene rate transmitted to NASA stations specified in this table. The system

shall be capable of providing scene-to-scene registration where the registration accuracy is within .3 pixel (90% of the time) for both MSS and TM images. The system shall provide capability to throughput 200 MSS scenes/day averaged over 10 days with 48 hour turn-around from DMS in to DMS out at launch of Landsat-D. When the Landsat-D' spacecraft is launched, the DMS capability shall support a combined Landsat-D and D' capacity of 200 MSS scenes/day with a 48 hour turn-around. In addition, at the launch of D' the DMS will have, in place, an R&D capability for TM. This R&D capability is to characterize the TM sensor performance, benchmark the TM R&D system performance and throughput capacity, and specify the system hardware and software for an operational TM data processing system. The OCC shall perform the functions of monitoring both Flight Segment operations, issuing commands to the Flight Segments and planning mission operations. The LAS shall provide the ability to analyze data to determine that mission objectives are being met. Each mission shall have a minimum life time of 3 years in orbit.

3.2

FLIGHT SEGMENT REQUIREMENTS

3.2.1

Flight Segment System Functions and Interfaces

3.2.1.1

Flight Segment Functions.

The primary functions of the Flight Segment system, defined as all on-orbit and associated launch and ground support equipment, shall be to:

- o Form images of the Earth by use of the MSS and TM instruments
- o Provide Radio Frequency (RF) links to transmit the images to the ground and the Tracking and Data Relay Satellite System (TDRSS).
- o Provide power to the Flight Segment instruments and support equipment.
- o Deleted
- o Provide attitude and orbital stability to the instruments.
- o Provide telemetry monitoring of vital Flight Segment functions.

Table 3.1.1-1
Landsat Required Scene Rate*

Instrument Users	MSS			TM		
	Scenes/ Day	Scenes/Night	Scenes/ 24 Hr	Scenes/ Day	Scenes/Night (thermal band)	Scenes/ 24 Hr
NASA Stations	200	0	200	70	30	100
Foreign Stations (real-time)	337	0	337	100	50	150

*To be used for sizing the power system.

- o Provide command capabilities to control Flight Segment operation from the ground.

3.2.1.2

Flight Segment Interface Requirements.

The Flight Segment shall interface with the following systems:

- o Data Management System (DMS) - The Flight Segment will transmit housekeeping and sensor data to TDRSS. Data will be recorded at the White Sands, N.M., station and played back to the DMS at GSFC via a Domsat link. Data will also be transmitted to the TGS, where it will be received, demodulated and transmitted to the DMS in real time. The Flight Segment will transmit MSS data to STDN stations at Goldstone and Alaska via S-Band until TDRSS becomes operational. At these stations, the MSS data will be recorded and played back to the Domsat Interface Facility where the MSS data will be recorded. The MSS data recordings will be hand carried from the Domsat Interface Facility to the DMS.
- o Operations Control Center (OCC) - The Flight Segment will interface with the OCC where telemetry outputs will be observed and captured and command transmissions generated. The prime interface to OCC shall be through RF S-band transmission by way of TDRSS and via GSTDN.
- o Foreign Users - The interface to foreign users shall be by direct RF transmission to the ground at X-band for TM and MSS data and S-band for MSS data alone.

3.2.2

Flight Segment Configuration Requirements

The major subsystems of the Landsat-D Flight Segment, in a Delta 3920 launch configuration, are represented schematically in Figure 3.2.2-1, for reference. The Flight Segment

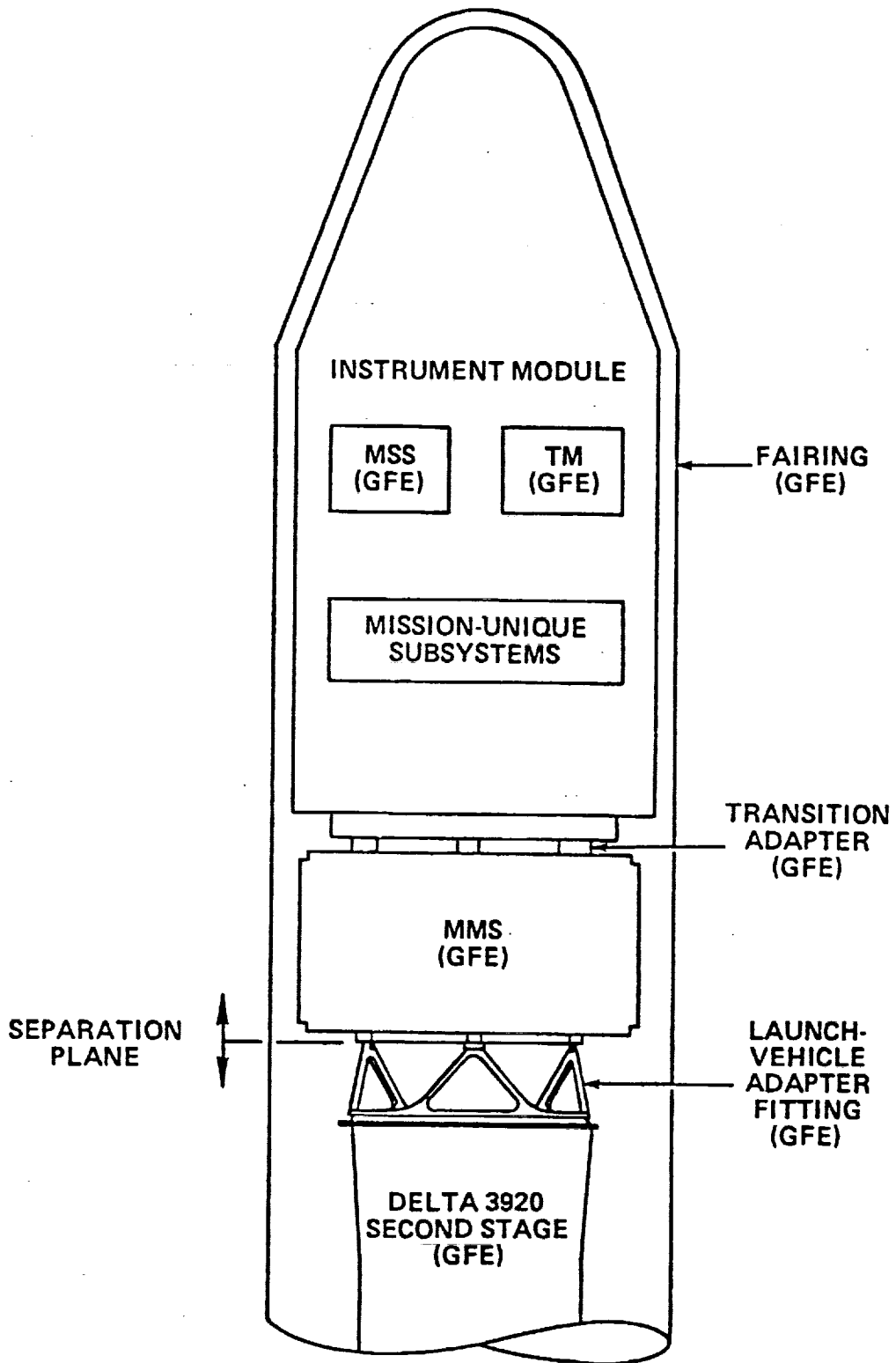


Figure 3.2.2-1. Schematic Representation of the Landsat Flight Segment Launch Configuration

shall consist of two major elements, the Instrument Module and the Multimission Modular Spacecraft (MMS), as shown in the figure. The MMS shall provide the major housekeeping and support functions to the Flight Segment while the Instrument Module shall contain the MSS and TM instruments, the GPS system and any Mission Unique Subsystems required to achieve Landsat-D Flight Segment objectives. The MSS and TM instruments and the MMS will be supplied as Government Furnished Equipment (GFE). The Landsat-D (Protoflight) Segment will include an MSS instrument and a TM instrument. In the event the TM instrument is not available, the Landsat-D segment will include a mass-thermal model of the TM instrument. The Landsat-D' Flight Segment will have both TM and MSS instruments. Further, the Flight Segment, wherever possible, shall utilize existing designs and hardware as identified in the Catalog of Available and Standard Hardware as defined in the document specified in Paragraph 2.2.1.1. The Flight Segment shall be designed to be retrievable by the Space Transportation System (STS).

The contractor shall propose a basic Flight Segment configuration indicating the relative position of the major subsystems in the Delta launch, nominal on-orbit, and retrieval modes and indicating stowing and deployment mechanisms and their operation. The overall configuration must be consistent with the requirements of the instruments (MSS and TM), MMS, launch vehicle, and STS. (See 2.1.8.3 and 2.1.8.4).

3.2.2.1

Fields of View and Orbital Orientation.

The Flight Segment configuration shall consider the orbital orientation and field of view requirements of the subsystem optics, thermal coolers, thermal louvers, antennas, and solar array with respect to objects including other Flight Segment subsystems, the Earth, Sun, TDRSS, S- and X-band ground stations, and GSTDN Stations. The Flight Segment shall provide the capability of an analog earth pointing control mode to ensure a sun safe instrument orientation. Hardware may be attached to the MMS structure only with GSFC approval.

The mission contractor shall supply Earth Sensor Assemblies (ESA) for Landsat-D and D' consisting of Earth Sensor Scanner (ESS), Earth Sensor Electronics (ESE) and interconnecting cables. Two of these ESA's will be supplied for each spacecraft. GSFC will integrate the ESS, ESE and cables into a Earth Sensor Assembly Module (ESAM) which will be designed, fabricated, assembled and tested at GSFC. The ESAM will be integrated into the MMS by GSFC personnel with support from the MMS Integration Contractor and the Landsat Mission Contractor.

3.2.3

Multimission Modular Spacecraft Requirements

The Landsat-D Flight Segment will utilize the capabilities of the MMS specified in Paragraph 2.1.2. The MMS will be used to provide mission services, including housekeeping communications and data handling, electrical power, and attitude and orbit control. Proposed designs of the Flight Segment must specify the required MMS Mission Options necessary to support the Flight Segment. These Mission Options may be chosen to increase the spacecraft reliability and/or capabilities under nominal operating conditions. For the purposes of this specification an MMS configuration for Landsat-D has been determined and is shown in Table 3.2.3-1. The bidder is encouraged to request modifications of this configuration by the inclusion or deletion of Mission Options during the proposal stage if these will lead to improved performance and/or more economic development of the Flight Segment. The requirements on the MMS subsystems and interface performance are specified in the following paragraphs. Mission options are defined in the document identified in Paragraph 2.1.2.2. The weight of the MMS will not exceed 2600 pounds including mission options and payload attach fittings and fully loaded with propellant.

3.2.3.1

MMS Structure/Mechanical Interfaces.

The MMS mechanical system is specified in the document identified in Paragraph 2.1.2.4 and shall interface with the Flight Segment Instrument Module in accordance with the document specified in Paragraph 2.1.2.2. The Instrument Module shall form a unified structure with the MMS structure to provide

compatibility and continuity between the Instrument Module and MMS in accordance with the requirements of the document specified in Paragraph 2.1.2.1.

3.2.3.1.1 Transition Adaptor

The Landsat-D Instrument Module shall structurally interface with the MMS at the MMS Transition Adaptor to conform with the requirements of the documents in Paragraphs 2.1.2.4 and 2.1.2.2 except that a mission unique transition adaptor will be used. The mission unique triangular transition adaptor is defined in 2.2.1.16. The Transition Adaptor shall form the structural interface and provide mechanical support to the Flight Segment during on-orbit retrieval or launch using the STS. The design of the Instrument Module shall not interfere with the operation of the Flight Support System (FSS) of the STS during retrieval or launch and shall be in accordance with the requirements of the document specified in Paragraph 2.1.2.1.

3.2.3.1.2 Launch Vehicle Adaptor Fitting

The Launch Vehicle Adaptor Fitting shall provide the interface between the MMS and the Delta 3920 launch vehicle as specified in the documents identified in Paragraphs 2.1.2.1, 2.1.2.2, and 2.1.2.4.

3.2.3.2 MMS Communications and Data Handling (C&DH) Subsystem.

The MMS C&DH shall provide an S-band communications system for housekeeping telemetry, command, and ranging; a computer system to carry out required on-board Flight Segment controls; and an interface system to Remote Interface Units (RIU) to gather housekeeping data from, and disseminate commands to, other Flight Segment Subsystems. Electrical connections between the MMS C&DH Subsystems and the Instrument Module shall be at connectors located at the Transition Adaptor as specified in the document identified in Paragraph 2.1.2.5.

3.2.3.2.1 C&DH Communications Performance

The C&DH Module, in conjunction with the Mission Unique C&DH S-band Antenna Subsystem

Table 3.2.3-1
MMS Configuration for each Landsat

Component	Quantity	Component	Quantity
Power		Mechanical/Structural System	
Battery (50 Ah)	3	Module frames	3
Power control unit	1	Module support structure	1
Power regulator unit	1	Transition adapter	1
Bus protection assembly	1	Module attachment hardware	1 set
Signal conditioning assembly	1	Miscellaneous hardware	1 set
Remote interface unit	2		
Attitude-control subsystem		Electrical System	
Magnetic Torquer	3	Modular/struc. connector	1 set
Attitude-control electronics	1	Spacecraft harness (including BCU)	1 set
Magnetometer	2	Signal cond. and control unit	1
Star tracker	2	RIU - Instrument Module*	Up to 27
Precision digital Sun sensor	1	BCU - Instrument Module*	Up to 6
Reaction wheel	4		
Inertial reference unit	1	Thermal System	
Remote interface unit	2	Louvers	6
Earth Sensor Assembly Module	2	Insulation (modules)	3
Communications and Data Handling		Insulation (spacecraft)	1
STACC central unit	2	Heaters and thermostats	1 set
Standard computer interface	2	Propulsion	
Premod processor	2	Rocket-engine module	4
Power control unit	2	Propellant tanks	4
Transponder	2	Interface/drive electronics unit	1
Onboard computer (OBC)	2	Latch valves and fittings	1 set
Remote interface unit	8	Remote interface unit	2
OBC memory 8000	2		
NBTR			

*Remote interface unit (RIU) and bus-coupling unit (BCU) quantities include TM and MMS requirements. These will be GFE up to the amount required by the contractor.

specified in Paragraph 3.2.4.3.2, will provide a means for range and range rate measurement for ground and on-board control of all spacecraft and payload sensor functions, and for transmission of housekeeping telemetry data. It will be utilized primarily with TDRSS. However, it will also be compatible with the GSTDN, which will be utilized for backup. All RF transmissions from the Landsat-D Flight Segment must meet the flux density requirements specified in the document in Paragraph 2.2.2.6 for transmission to the ground and in Paragraph 2.1.5.1 for transmission to TDRS. Operational constraints can be used as one criterion in meeting these requirements, but this should be kept to a minimum. The C&DH Module will utilize two multimode GSTDN/TDRSS versions of the NASA Standard Transponder as delineated in Paragraphs 2.1.2.6 and 2.1.5.2. The overall communications performance via TDRSS shall be as specified in Paragraph 2.1.5.1. The overall communications performance via GSTDN shall be compatible with GSTDN ground stations with the parameters as delineated in Table 3.2.3.2.1-1. Foreign users may receive housekeeping telemetry on this link. Assume that the foreign user ground station parameters are the same as STDN.

Table 3.2.3.2.1-1

GSTDN GROUND STATION PARAMETERS

Housekeeping Telemetry Reception

<u>Parameter</u>	<u>Value</u>
Receive Frequency (nominal)	2287.5 MHz
Receive Antenna Gain	44 dB*
Receive Antenna Pointing Loss	Negligible
Polarization	Simultaneous Diversity Reception Available. Antennas are either circular or linear polarized
Minimum Antenna Elevation Angle	5°
System Noise Temperature	125° K @ 5° Elevation angle
Receiver Circuit Loss	0 dB**
Demodulator Degradation	3 dB

Command Transmission

<u>Parameter</u>	<u>Value</u>
Transmission Frequency (nominal)	2106.4 MHz
Transmitter Power	+ 63 dBm
Transmitter Antenna Gain	+ 43 dB
Polarization	Right Hand Circular
Minimum Antenna Elevation Angle	0°

* 9 meters (30 feet)

** Included in antenna gain

3.2.3.2.1.1 Telemetry Channel

When operated with either the TDRSS or the GSTDN, the link shall not cause the housekeeping telemetry bit error rate to exceed 10^{-5} . When operated with the TDRSS, the housekeeping telemetry shall be capable of being continuously transmitted whenever the Landsat-D satellite and any of the Tracking and Data Relay Satellites are mutually visible.

3.2.3.2.1.2 Command Channel

The C&DH Subsystem will be capable of detecting and decoding NRZ-M commands at a high rate of 2 Kbps (GSTDN), a medium rate of 1 Kbps (TDRS), and a low rate of 125 bps (TDRS).

The 2-Kbps NRZ-M command signal will be PSK-modulated on a 16-KHz sinusoidal subcarrier and will be compatible with the GSTDN. The medium and low rate NRZ-M commands will be PSK-modulated on a PRN code and will be compatible with the TDRSS. The command detectors within the transponders will be capable of detecting both command modulation modes.

When operated with the TDRSS or the GSTDN, the link shall be available, on a scheduled basis, whenever the Landsat-D Flight Segment and any of the TDRS's and/or the GSTDN ground stations are mutually visible, except where pointing restrictions make transmission impossible. The system shall be designed to keep zones of exclusion to a minimum and away from areas of interest.

3.2.3.2.2 C&DH Data Handling Functions

The MMS C&DH Subsystem will perform the functions described in the following paragraphs.

3.2.3.2.2.1 Flight Segment Subsystem Control

The C&DH On-Board Computer, as specified in Paragraph 2.1.2.6, has been designed to control automatic housekeeping functions. It shall be used, when practical, to handle all

such functions. As a minimum it shall be used to control the following functions: attitude control, power system monitoring, solar array pointing, high gain antenna pointing, and sending stored commands at specified times. The Flight Segment contractor shall provide all software for these functions. The on-board computer (OBC) cycle time shall be 1.111 microseconds. (This cycle time (1.111 microseconds) supercedes the OBC cycle time given in all referenced documents).

3.2.3.2.2.2 Housekeeping Telemetry Acquisition

Housekeeping telemetry shall be acquired by a number of Remote Interface Units (RIU's) distributed throughout the Flight Segment. The application of the RIU's shall conform to the specification in Paragraph 2.1.2.11. Telemetry is transmitted from the RIU to the Central Unit of the C&DH Subsystem. The C&DH Subsystem shall perform telemetry data input, telemetry format control, data output of real-time telemetry, Tape Recorder dumps, Payload Correction Data Telemetry, and OBC data dumps directly to the premodulator processor as specified in the document in Paragraph 2.1.2.6. The capability shall be provided to simultaneously transmit real-time housekeeping data and OBC memory data dump or Payload Correction Data telemetry, or tape recorder dump, in the TDRSS SSA mode and to the GSTDN. Housekeeping telemetry shall be either selected SSA or SMA mode. Provisions shall be made to transmit to TDRS with one transponder and STDN with the other transponder simultaneously.

3.2.3.2.2.3 Command Processing

The MMS C&DH Subsystem shall receive, decode, verify, and store or distribute commands to the Flight Segment. Commands shall be distributed via the RIU's to addressed Flight Segment Subsystem command points in conformance with the document specified in Paragraph 2.1.2.6. Delayed commands shall be stored in the On-board Computer memory until execution.

3.2.3.2.2.4 Flight Segment Timing

The MMS C&DH Subsystem shall provide a reference oscillator clock signal to be used

as a standard throughout the Flight Segment. This clock signal shall be in conformance with the document in Paragraph 2.1.2.6. The Flight Segment contractor shall provide and integrate a mission unique subsystem that will generate GMT from the MMS oscillator. This time shall be inserted in the video of both the TM and MSS instrument. This time code will be transferred to the instrument on receipt of a request from the instrument. This time code shall also be inserted into the C&DH realtime telemetry stream. The time code interface requirements for the TM, MSS, and C&DH are described in 2.1.3.1, 2.1.4.1, and 2.1.2.11 respectively.

To minimize flight software complexity, precision timing requirements will be maintained by periodic ground uplink of timing corrections to the mission unique clock.

The Flight Segment contractor shall provide a mission unique oscillator for the Protoflight and Flight systems. These units will be used to supplement the oscillator used in the C&DH module. The Flight Segment contractor will supply the units and interface information to the MMS integration contractor who will install the oscillators in two C&DH modules. The oscillator specifications will be based on the ground processing accuracy requirements needed to prevent clock updates more frequent than once per orbit. This oscillator shall be powered from the unregulated power bus.

3.2.3.2.2.5

C&DH On-board Recorder

The MMS C&DH System for the Landsat-D shall include two (2) 10^6 standard tape recorders (STR) as defined in paragraphs 2.1.10.1 and 2.1.10.2.

3.2.3.3

MMS Power Subsystems

Electrical power for the MSS and TM instruments and other Flight Segment Subsystems shall be provided by the MMS Power Subsystems and the Instrument Module shall conform to the documents specified in Paragraphs 2.1.2.5 and 2.1.2.17. The Power Subsystem shall provide power adequate to allow the instrument usage specified in Table 3.1-1. The power distribution for the Flight Segment is defined in item 3.3.1 of Paragraph 2.1.2.1. Bus protection is defined in item 3.2.4.1 of paragraph 2.1.2.5. The mission contractor shall provide power switching and power bus protection for all GFE that is integrated into the instrument module.

3.2.3.3.1

Solar Array Power Input

The MMS Power Subsystem shall input power from a Solar Array consistent with the Flight Segment power Requirements. The Solar Array shall be a Mission Unique Subsystem and part of the Instrument Module. The input power from the Solar Array must conform to the requirements of the document specified by Paragraph 2.1.2.7 except that the Solar Array shall provide a minimum max. power point voltage of 44VDC at end of mission (EOM) with sufficient margin provided to assure that the 44VDC value is not violated.

3.2.3.3.2

Energy Storage

The MMS Power Subsystem shall be capable of storing the energy required to sustain the instruments through both day and night operation as described in Table 3.1-1. The MMS energy storage capability is specified by the document in Paragraph 2.1.2.7.

3.2.3.3.3

Power Distribution

The Power Subsystem shall distribute bus power at +28V nominal voltage to the MMS subsystems and the Instrument Module, consistent with the document specified in Paragraph 2.1.2.7, except that the power supplied to the instrument module shall be by redundant +28 vdc buses A and B. This bus power is required to sustain the Flight Segment through both day and night operations of the MSS and TM instruments, which operate either simultaneously or singly, and associated Flight Segment subsystems, including Ku-, X-, and S-Band simultaneous operation.

3.2.3.3.4

Signal Conditioning and Control Unit

The SC&CU provides control and monitoring functions for the MMS and the payload which are not directly related to the major subsystem modules. Circuit redundancy is provided for all critical functions so that the SC&CU will not have to be resupplied while in orbit. Command capability is limited to that of a redundant set of RIU's. Telemetry capability is limited to that of a redundant set of RIU's. The SC&CU provides for the following types of mission unique control functions:

- o Payload heater power fusing and control
- o Arming circuits for pyrotechnic devices
- o Firing circuits, subordinate to the arming circuits for pyrotechnic devices
- o Spare Command and Telemetry interfaces
- o Appendage jettison circuitry

The SC&CU used shall be the one described in Paragraphs 2.1.2.13 and 2.1.2.16.

3.2.3.4

Attitude Control and Orbital Stabilization Subsystems. The Flight Segment will maintain attitude control by utilization of the MMS Attitude Control System (MACS) and will maintain the required orbit by utilization of the MMS Propulsion Subsystem defined in paragraph 2.1.2.14. The electrical interface between the ACS and the Instrument Module shall conform with the document specified in Paragraph 2.1.2.2.

3.2.3.4.1

Attitude Control

The Flight Segment shall utilize the MMS Attitude Control Subsystem, as specified in the document identified by Paragraph 2.1.2.8, to control Flight Segment pointing and attitude rates. This system, together with the appropriate telemetry, shall be sufficient to achieve the required accuracy when utilizing geodetic control points in ground processing.

3.2.3.4.2

Antenna and Solar Array Pointing

The contractor shall provide pointing control to the Mission Unique antenna system and Solar Array as required. In both the mission unique antenna system and Solar Array Drive system the contractor shall provide electrical and

mechanical redundancy for all moving parts, sufficient to prevent single point failures resulting in abnormal performance. The output shaft bearing of the SAD need not be redundant. The contractor may utilize the services of the On-board Computer (Paragraph 2.1.2.12).

3.2.3.4.3 Orbital Stabilization

The Flight Segment will be provided with a subsystem to maintain the fine accuracy of the orbital altitude and inclination required to obtain a precise swath pattern which will repeat each 16 day cycle within +5 km maximum. The mean solar time of the descending node shall be maintained at 9:45 AM + 15 minutes. In addition to maintaining the required altitude accuracy, the subsystem will be capable of removing launch vehicle induced orbit errors, up to 3 sigma.

3.2.3.5 Thermal Interfaces

MMS thermal interfaces are specified in the documents in Paragraphs 2.1.2.1, 2.1.2.2., 2.1.2.3. Thermal control heaters shall be sized based on a bus voltage variation of 25 to 33 volts.

3.2.4 Instrument Module

The Flight Segment shall incorporate the Multispectral Scanner and Thematic Mapper instruments. A TM mass/thermal model for Landsat-D will be provided by GSFC. This model will be used only if necessary to preserve the Landsat-D launch dates. Each Flight Segment Instrument module has mission unique Subsystems required to achieve the Landsat-D Flight Segment mission objectives. The Instrument Module shall provide support for the instruments and Mission Unique Subsystems which shall include, but not be limited to, a Wideband Communications Subsystem, Global Positioning System equipment, Antenna Subsystem, Solar Array, Electrical Subsystem, Structural Subsystem, and Thermal Subsystem. In the following paragraphs, the Instrument Module configuration requirements and the functional and interface requirements of the instruments and Mission Unique Subsystems are specified.

3.2.4.1 Instrument Module Configuration

The Instrument Module configuration shall be consistent with the requirements of the Flight Segment configuration as specified in Paragraph 3.2.2.

3.2.4.2 MSS and TM Instruments

3.2.4.2.1 Multispectral Scanner (MSS) Interface Requirements

3.2.4.2.1.1 Mechanical Interfaces

The mechanical interfaces between the MSS and the Instrument Module shall conform to the requirements of Paragraphs 2.1.4, 2.1.4.4, and 2.1.4.5. The MSS consists of a scanner and multiplexer. The interconnecting cable will be supplied by the mission contractor. The total weight of the MSS scanner and multiplexer will be less than 64.86kg (143 lbs.). The flight segment shall satisfy the requirements for scanning, radiation fields-of-view as well as boresight and scanning direction as specified in Paragraphs 2.1.4.1 and 2.1.4.4.

3.2.4.2.1.2 Thermal Interface

The Instrument Module shall provide temperature control for the MSS of $20^{\circ} \pm 10^{\circ}\text{C}$ under normal orbital operating conditions.

Thermal control will be provided to protect the instrument in the Safe Hold Mode and during launch and acquisition periods to the survival limits specified in Paragraph 2.1.4.1.

3.2.4.2.1.3 MSS Wideband Data

The MSS data format is specified in Paragraph 2.1.4.1. The 15.06-Mbps data stream from the MSS shall be transmitted via the Ku-band transmitter to TDRSS for domestic users. The MSS data shall be transmitted via S-band and X-band to ground users. The mission contractor shall be required to reclock the MSS data and provide differential encoding in order to resolve the "1" and "0" ambiguity (for Ku-Band and X-Band transmission only).

3.2.4.2.1.4

MSS Housekeeping Telemetry and Commands

Housekeeping and command telemetry data shall interface with the Instrument Module through the Remote Interface Units (Paragraph 2.1.2.11).

3.2.4.2.1.5

Power

The Instrument Module shall distribute power from the MMS to the MSS with the characteristics specified in Paragraph 2.1.4.1.

3.2.4.2.1.6

Pointing Accuracy

Pointing accuracy and pointing measurement shall be consistent with system pixel registration requirements as specified in Paragraph 3.1. Attitude control, thermal distortions of the Flight Segment, and other factors which affect MSS pointing must be considered.

3.2.4.2.2

Thematic Mapper (TM) Interface Requirements

3.2.4.2.2.1

Mechanical Interfaces

The mechanical interfaces between the TM and the Instrument Module shall conform to the requirements of Paragraphs 2.1.3.1, and 2.1.3.2. The total weight, dimensions, moments of inertia, centers-of-gravity locations, and angular moments are specified in paragraph 2.1.3.1. The total weight of the TM scanner and multiplexer will be less than 258 Kg (570 lbs).

3.2.4.2.2.2

Thermal Interface

The thermal conductive coupling between the Instrument Module and the TM shall be no more than 0.8 Watts/ $^{\circ}$ C. The heat flow from the TM to the Instrument Module shall not exceed ± 10 Watts. Under normal orbital operating conditions the TM design shall provide this isolation at a minimum. The instrument Module shall provide a mounting temperature for the TM of $20 \pm 10^{\circ}$ C under normal orbital operating conditions and launch. Thermal control will be provided by the instrument contractor to protect the instrument in the safe hold modes and during launch and acquisition periods to the survival limits specified in paragraph 2.1.3.2.

3.2.4.2.2.3

TM Wideband Data

The TM data format and data specifications are in Paragraphs 2.1.3.1 and 2.1.3.2. The TM data output will be Pseudo-noise (PN) encoded. The mission contractor shall be required to reclock the TM data and provide differential encoding in order to resolve the logic "1" and "0" ambiguity. The TM produces approximately an 85 Mbps bit stream in all operating modes. Provisions shall be made to incorporate Payload Correction Data (PCD) telemetry in the TM data stream. The Flight Segment contractor shall provide interface buffers between the PCD Telemetry Multiplexer and the TM which shall output PCD telemetry data to the TM on request from TM. This data shall be transferred in a synchronous mode to the TM. Interface requirements for this mode are defined in Paragraph 2.1.3.1.

The Flight Segment contractor shall interface the time code from the MMS as defined in Paragraph 3.2.3.2.2.4. All sensor data are transmitted via the Wideband Communications at Ku-band and at X-band.

3.2.4.2.2.4

TM Housekeeping Telemetry and Commands

The TM telemetry interface shall meet the requirements of Paragraph 2.1.3.1.

3.2.4.2.2.5

Power

The TM power system requirements are specified in Paragraph 2.1.3.1. The TM power is as follows:

- 300 watts - average operations
- 365 watts - peak operations
- 75 watts - standby, maximum
- 14 watts - launch mode, maximum

All references to the power requirements of the TM contained in this specification (GSFC-430-D-100) and its associated reference specifications shall be as above.

The mission contractor shall incorporate, as an external part of the IM power distribution system, two + 19 volt DC power sources to provide external standby heater power to the TM in accordance with the requirements specified in the reference document of 2.1.3.1.

3.2.4.2.2.6 Pointing Accuracy

Pointing accuracy and pointing measurement shall be consistent with system pixel requirements as specified in Paragraph 3.1. Attitude control, thermal distortions of the Flight Segment, and other factors which affect the TM pointing must be considered.

Angular Displacement Sensor Assemblies (ADSA) will be implemented on Landsat-D and D'. The ADSA consists of three single axis ADS units mechanically packaged in a tri-axial configuration, along with presample filters and interface electronics. GSFC shall design and fabricate ADSA mounting brackets to the Thematic Mapper mechanical and thermal interfaces. The mission contractor will supply the ADS and will design, build, and test the formatter of the ADS Electronics (ADSE) which is housed in the Power Distribution Unit (PDU). GSFC shall design, build, test and calibrate the ADS electronics and mechanical package located with the ADS's. The mission contractor shall supply the interconnecting harness. The electrical integration shall be done by the mission contractor with GSFC support.

3.2.4.3 Mission Unique Subsystems

3.2.4.3.1 Wideband Communications Subsystem

3.2.4.3.1.1 Function

The contractor shall provide, as part of the Instrument Module, a Wideband Communications Subsystem for transmitting the TM and MSS data to selected recipients. The Wideband Communications Subsystem shall consist of the components, cabling, waveguide and connectors necessary to receive digital data signals from the MSS and TM sensors, to combine the data to form each of several data output combinations, to modulate the selected (via command) data outputs onto the appropriate RF carriers, to amplify the RF signals, and to transmit each

RF signal from its appropriate antenna to receiving terminals with characteristics as delineated in Paragraph 3.2.4.3.1.2. All RF transmission from the Wideband Communication Subsystem must meet the flux density requirements specified in the document in Paragraphs 2.2.2.6 and 2.1.5.1.

The Wideband Communications Links, S-Band, X-Band, and Ku-Band shall, except for the TDRS, Omni, S-Band, and X-Band antennas, be completely redundant.

Provisions should be made to operate the wideband and housekeeping telemetry S-band links, the X-band link, and the Ku-band link simultaneously for limited periods. Provisions should also be made to operate each link independently. Switching shall be provided that allows independent selection of the modes shown in Table 3.2.4.3.1.3-1 for all RF carriers simultaneously. The selection of a different mode for a transmitter shall not cause any interruption in transmission of sensor data that is contained in both modes or sensor data on another carrier.

3.2.4.3.1.2

Overall Performance

The TDRSS Ku-band Single Access (KSA) Return Link Service will be the primary wideband data reception subsystem of the Space Tracking and Data Network (STDN) that will be used to service Landsat-D. The TDRSS characteristics are as specified in Paragraph 2.1.5.1. There will be wideband data receiving sites at S-band and/or X-band throughout the world. These sites will be scheduled considering available spacecraft power and thermal limitations. The S-band and X-band wideband ground station parameters for use in link calculations are delineated in Table 3.2.4.3.1.2-1. When operated with an S-band or X-band ground station, these links shall not cause the MSS bit error rate to exceed 10^{-5} . The Thematic Mapper (TM) link at both Ku-band and X-band shall be designed for a bit error rate not to exceed 10^{-6} . A minimum of 4.7dB link margin shall be designed into the Ku-band link. The S-band and X-band links shall have a minimum of 3dB margin.

Table 3.2.4.3.1.2-1
S-Band and X-Band Wideband Receiving Ground-Station Parameters
for GSTDN and Foreign Users

<u>Parameter</u>	<u>S-Band</u>	<u>X-Band</u>
Frequency band	2200 to 2300 MHz	8025 to 8400 MHz
Receiver frequency	2287.5 MHz, 2265.5 MHz	8.2125 GHz
Antenna dish diameter	9 meters (30 feet)	9 meters (30 feet)
Receiver antenna gain (including pointing loss)	+44 dB	+54 dB
Receiving system noise temperature	125K at 5° elevation angle	200K at 5° elevation angle, (no precipitation)
Minimum antenna elevation angle	5°	5°
IF bandwidth	20 MHz (1 dB points) 28 MHz (3 dB points)	170 MHz
Precipitation	Not applicable	4 mm per hour
GND demodulator loss	3 dB	2.5 dB
System margin (including precipitation effects)	3 dB	3 dB

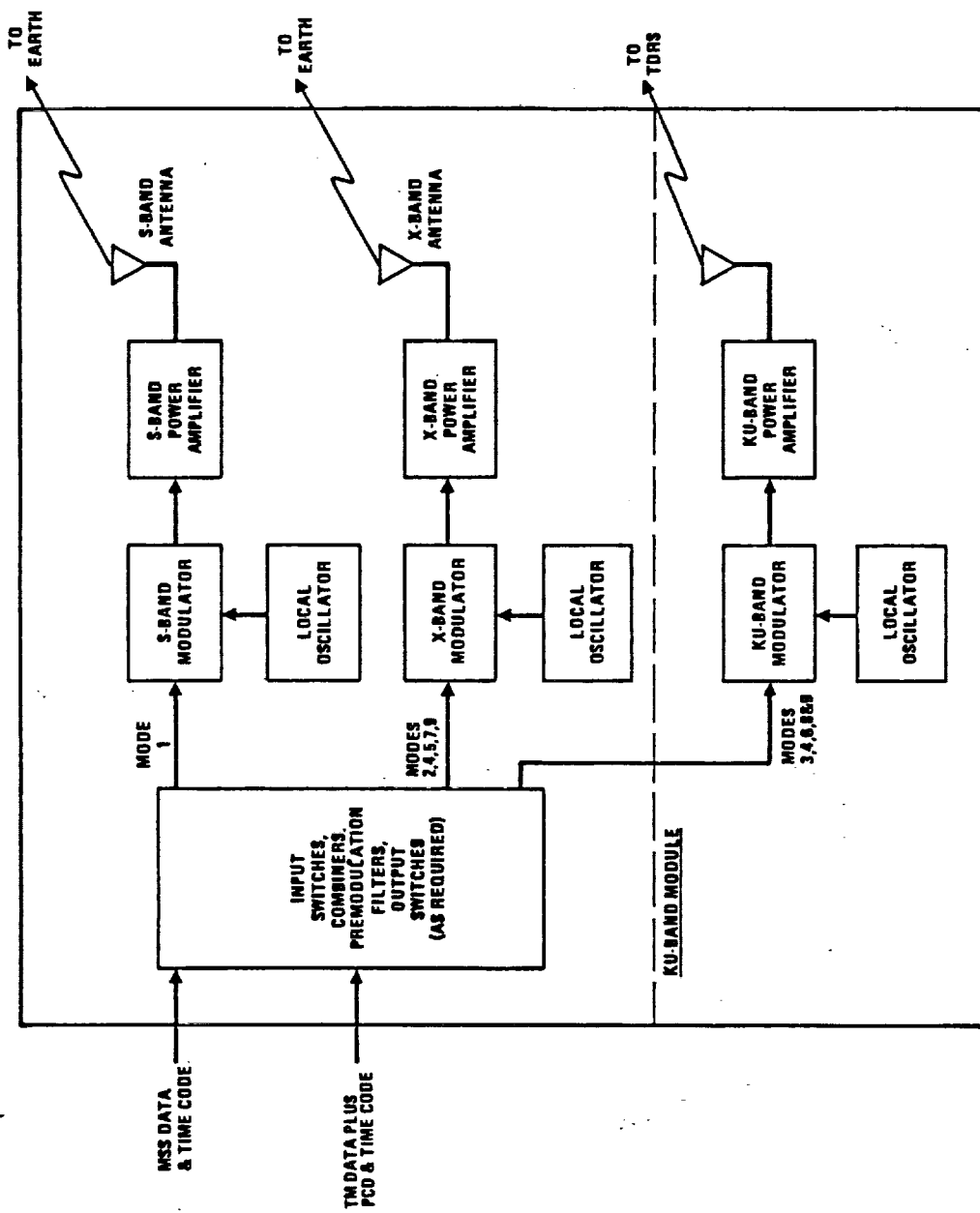


Figure 3.2.4.3.1.3-1. Wideband Communications Subsystem

3.2.4.3.1.3

Subsystem Characteristics

Figure 3.2.4.3.1.3-1 is a functional block diagram of the Wideband Communications Subsystem. The Wideband Communications Subsystem may consist of two modules - the Wideband Communications Module and the Ku-band Module. The functional block diagram is for descriptive purposes only. The contractor shall determine the actual physical configuration necessary to accomplish the functions of the Wideband Communications Subsystem. The contractor shall also consider the requirements of the C&DH S-band antenna system specified in Paragraph 3.2.4.3.2 in determining the actual physical configuration.

The inputs shall be an MSS signal from the MSS instrument and a TM signal from the TM instrument. Payload Correction Data (PCD) signals shall be routed to the TM for multiplexing with the TM instrument data. The approximate signal bit rates will be as follows:

MSS: 15.06 Mbps

TM: 85 Mbps (all bands)

Flight Segment Housekeeping
Telemetry: (to be proposed
by contractor)

Data output modes shall be available and selectable by command. these modes shall be as shown in Table 3.2.4.3.1.3-1.

The MSS shall frequency modulate the Wideband S-band transmitter with a nominal peak single-sided frequency deviation of 5.6 MHz resulting in a video/FM spectrum limited to 20 MHz (+ 10 MHz about the carrier). The RF link shall be designed to achieve a 10^{-5} BER for elevation angles down to 5 degrees.

The Ku-band carrier shall be angle modulated by the combinations of TM and MSS data as shown in Table 3.2.4.3.1.3-1 and with parameters consistent with the constraints of Paragraph 2.1.5.1.

The X-band carrier shall be angle modulated by

the modes shown in Table 3.2.4.3.1.3-1 with parameters the same as those used for the Ku-band carrier. The error budget distribution can be determined by the contractor as long as the total link meets the BER requirement.

Each of the modulated RF carriers shall be amplified to an RF power output level that, when combined with the antenna requirements subsequently specified, results in the overall performance specified in Paragraph

3.2.4.3.1.2. Each modulated and amplified S-band and/or X-band signal shall feed a separate antenna. The design requirements for each of the antennas are delineated in Table 3.2.4.3.1.3-2. The modulated and amplified Ku-band signal shall feed a Ku-band antenna that has the capability to both program track and Ku-band autotrack the Tracking and Data Relay Satellites as specified in Paragraph 2.1.5.1. The Ku-band shall have a minimum margin of 3.7db in the program track mode. The design requirements for the antenna are delineated in Table 3.2.4.3.1.3-3. The Ku and X-Band links need not be tested for spurious PM and Phase Noise below 1kHz, as defined in the TDRSS User's Guide STDN 101.2, Revision 4.

3.2.4.3.2

C&DH S-Band Antennas Subsystem

The contractor shall provide, as part of the Instrument Module, a C&DH S-band Antenna Subsystem for use with the MMS C&DH Module delineated in Paragraph 3.2.3.2. The C&DH S-Band Antennas Subsystem shall consist of the antenna elements, couplers, hybrids, circulators, cabling, and connectors necessary to radiate signals to, and receive signals from, both TDRSS and GSTDN, with a combined performance as defined in Paragraph 3.2.3.2.1. The C&DH S-band Antennas Subsystem shall functionally consist of two assemblies: the C&DH S-band Omni Antenna Assembly; and the C&DH S-band High Gain Antenna Assembly. The design requirements for each assembly are delineated in Tables 3.2.4.3.2-1 and 3.2.4.3.2-2 respectively. The antennas shall be configured to provide the following modes of operation:

Table 3.2.4.3.1.3-1
Data Output Mode Combinations

Data Mode	Combined Data	RF Output		
		S-Band	X-Band	Ku-Band
1	MSS Sensor	X		
2	MSS Sensor		X	
3	MSS Sensor			X
4	MSS Sensor		X	X
5	TM Sensor		X	
6	TM Sensor			X
7	MSS Sensor and TM Sensor		X	
8	MSS Sensor and TM Sensor			X
9	MSS Sensor and TM Sensor		X	X

Switching shall be provided that allows independent selection of modes for all three RF units simultaneously. The selection of a new mode for a transmitter shall not cause any interruption in data transmission of sensor data that is contained in both modes. In addition these changes in modes should not cause any interruption in data transmission for the other RF links.

Table 3.2.4.3.1.3-2
Wideband Antenna Characteristics

Parameter	Value
<u>S-Band</u>	
Polarization	Right-hand circular
Frequency	2265.5 MHz
Power handling	Up to 1 dB greater than that determined as a result of paragraph 3.2.4.3.1.3
Coverage	As required to provide an approximately constant power density on Earth for a subtended angle about the spacecraft Earth-pointing axis $\pm 63.8^\circ$
Gain	Determined along with RF power amplifier output value as a result of paragraph 3.2.4.3.1.2
<u>X-Band</u>	
Polarization	Right-hand circular
Frequency	8.2125 GHz
Power handling	Up to 1 dB greater than that determined as a result of paragraph 3.2.4.3.1.3
Coverage	As required to provide an approximately constant power density on Earth for a subtended angle about the spacecraft Earth-pointing axis of $\pm 63.8^\circ$
Gain	To be determined along with RF power output as a result of paragraph 3.2.4.3.1.2

Table 3.2.4.3.1.3-3
Wideband Ku-Band Antenna Characteristics

Parameter	Value
Polarization	Right-hand or left-hand circular (as selected by the contractor)
Frequency	See paragraph 2.1.5.1
Power handling	Up to 1 dB greater than that determined as a result of paragraph 3.2.4.3.1.3
Coverage	360 degrees in azimuth about the spacecraft Earth-pointing axis. From 65 to 180 degrees in elevation from the spacecraft Earth-pointing axis.
Gain	Determined along with RF power amplifier output value as a result of paragraph 3.2.4.3.1.2
Axial Ratio	<1.5 dB over 3-dB beamwidth
Steering Information (options)	Autotrack using TDRSS KSA forward link service, as specified in paragraph 2.1.5.1 and program track using either onboard computations or ground commands.
Pointing accuracy	Compatible with the above and the requirements of the MMS attitude control subsystem as delineated in paragraph 3.2.3.4.
Maximum slew rate	
Acquisition	
Tracking	
Handover	

LANDSAT-D

S-BAND C&DH

<u>ANTENNAS</u>	<u>MODE</u>	<u>FUNCTION</u>
OMNI	TDRS SSA	R.T. TLM, CMD & RANGING
OMNI	STDN	R.T. TLM, OBC DATA, RANGING CMD, PCD TLM, TR DUMP
OMNI	FOREIGN USER	R.T TLM, PCD TLM
HIGH GAIN	TDRS SMA	R.T. TLM, RANGING, CMD
HIGH GAIN	TDRS SSA	R.T. TLM, OBC DATA, RANGING, CMD, PCD TLM, TR DUMP

The C&DH module standard configuration does not provide for receiving commands from TDRS using the High Gain Antenna. The contractor shall provide an RF network external to the MMS which will provide this capability.

3.2.4.3.3

Solar-Array

A solar array shall be provided as a Mission Unique Subsystem to provide input power to the MMS Power Subsystem. This array shall provide the power requirements to support the Flight Segment mission operating needs and shall be compatible with the envelope requirements of the Delta 3920 launch vehicle fairing and the envelope and safety requirements of STS as specified in Paragraph 3.2.5. This solar array shall be sized to assure a positive power margin at end-of-mission (three years at summer solstice).

3.2.4.3.4

Electrical Subsystem

The Instrument Module shall contain a Mission Unique Electrical Subsystem. This Electrical Subsystem shall provide interconnection, distribution, and compatibility between the power and data handling subsystems of the instruments, the MMS, and other Mission Unique Subsystems in the Instrument Module. This subsystem shall consist of an electrical harness and other equipment including RIU's as required to acquire Instrument Module housekeeping telemetry and to distribute commands to the Instrument Module Instruments and Mission Unique Subsystems.

Table 3.2.4.3.2-1
C&DH S-Band Omnantenna Assembly Requirements

Parameter	Value
Bandwidth	2025 to 2300 MHz
Coverage	Spherical
Minimum gain over sphere	Gain will be determined by the requirement to transmit and receive housekeeping telemetry and commands from both TDRS and GSTDN over 85 percent of a sphere
Polarization	Right-hand circular
Connections	Independent connections as per paragraph 2.1.2.6 to C&DH module/structure interface connector omni RF ports 1 and 2
Source impedance	50 ohms
Power handling capability	6 watts minimum

Table 3.2.4.3.2-2
C&DH S-band High-Gain Antenna Assembly Requirements

Parameter	Value
Bandwidth	2025 to 2300 MHz
Coverage	360 degrees in azimuth about the spacecraft Earth-pointing axis; from 65 to 180 degrees in elevation from the spacecraft Earth-pointing axis.
Polarization	Left-hand circular
Gain	Determined by requirements of paragraph 3.2.3.2.1
Axial ratio	≤1.5 dB over 3-dB beamwidth
Source impedance	50 ohms
Power handling capability	6 watts minimum

3.2.4.3.5 Thermal Subsystem

The Instrument Module shall contain a Mission Unique Thermal Subsystem to provide the thermal control required for Mission Unique Equipment. The conductive interfaces to the MSS and TM instruments and the MMS are specified in Paragraph 3.2.3.5 for the MMS, paragraph 3.2.4.2.1.2 for the MSS, and Paragraph 3.2.4.2.2.2 for the TM.

3.2.4.3.6 Structural Subsystem

The Instrument Module shall provide a Mission Unique Structural/Mechanical Subsystem to provide structural support to the Instrument Module and to interface with the MMS Transition Adaptor and the instrument mechanical interfaces.

3.2.4.3.7 Other Mission Unique Subsystems

Other Mission Unique Subsystems shall be provided as required to achieve the Landsat-D Flight Segment Mission objectives.

3.2.4.3.8 Global Positioning System (GPS)

The GPS is a Department of Defense program designed to provide very precise position and timing information. The GPS to be flown on Landsat-D will be operated in two phases. The first phase will be a calibration one during which validation and calibration of the position and timing information will be performed. The second phase will call for the operational use of the GPS data. During the calibration phase the primary objective will be to validate the position and timing data for the GPS operational mode. A secondary objective will be to investigate the effects of various degrees of GPS coverage, different GPS operating modes, and variations in the on-board processing software and associated data base. During the operational phase the GPS will support two basic functions:

- o The position and velocity will be provided to the OBC to be used to provide earth reference for the Attitude Control System (ACS) control laws.
- o The position and velocity will be provided as ancillary data to the On-Board Computer (OBC) for transmission to the ground.

The GPS system will ultimately consist of 24 satellites - eight satellites in each of three orbital planes inclined at 63 ± 0.67 degrees to the Earth's equator and separated by 120 degrees at the equator. The orbits are to be nearly circular with a period of 12 hours. During the Landsat-D period, it is expected that only six satellites will be in operation. A GPS system containing the following components will be flown on Landsat-D:

- o GPS L-band antenna(s) and preamplifier(s)
- o A dual channel GPS receiver which can be commanded to operate as a single channel receiver.
- o A navigation computer (processor) which can be reprogrammed from the ground.
- o Data storage capability such that both raw GPS data and computer ephemeris data and time can be transmitted to the ground.

3.2.4.3.8.1 System Requirements

Flight Segment contractor shall provide the following functions:

- o Provide command and telemetry interfaces with the Flight Segment compatible with ICD referenced in Paragraph 2.1.9.3.
- o Deleted
- o Provide software to use GPS data for ACS control.
- o Make provisions for inserting spacecraft position data derived from the GPS into the housekeeping telemetry.
- o Provide thermal blankets and/or heaters and/or louvers required to meet the thermal requirements of the GPS.

3.2.4.3.8.2 GPS Antenna Requirements

An L-band antenna shall be supplied that meets the following requirements:

- o Frequency Range - 1.2 GHz to 1.6 GHz
- o Coverage - 360° in azimuth about the Flight Segment Earth pointing axis. From 90° to 180° in elevation from the Flight Segment Earth pointing axis.
- o Gain over 85% of the area defined shall be above -2 dbi
- o Polarization - Right Hand Circular Polarized

3.2.4.3.8.3 GPS Preamplifier Requirements

One or more L-band Preamplifiers shall be supplied that meet the following requirements:

- o Operating Frequencies - 1575.42 MHz and 1227.60 MHz
- o Bandwidth - 28 MHz \pm 7 MHz (-1db) about L_1 and L_2 .
- o Gain - +35 db \pm 3db.
- o Noise Figure - less than 4.5 db.
- o Image Noise Reduction - -5db reduction of L_1 noise at 1207 \pm 10 MHz, 15db reduction of L_2 at 859 \pm 10 MHz.
- o Out of Band Interference - -30db over the frequency range 50 MHz to 1127 MHz, 1290 to 1400 MHz, and 1675 MHz to 18 GHz.
- o Group Delay Variation - Less than 10 nanoseconds peak-to-peak within a \pm 8 MHz band about L_1 and L_2 .

3.2.4.3.8.4 GPS Reference Oscillator

The Flight Segment contractor shall provide an oscillator that interfaces with the Receiver/Processor Assembly (R/PA). The oscillator shall accept power from the R/PA power supply. One output from the oscillator shall be provided. The oscillator shall meet

the following characteristics:

- o Frequency - 5.115 MHz \pm 1 Hz
- o Amplitude - 800 \pm 100 mvpp into 50 ohms
- o Stability:

Averaging Time	RMS Stability
----------------	---------------

10 ms	$< 5 \times 10^{-9}$
100 ms	$< 6 \times 10^{-11}$
1 sec	$< 1 \times 10^{-11}$
10 sec	$< 1 \times 10^{-12}$
100 sec	$< 4 \times 10^{-12}$

- o Drift - 5×10^{-10} /day maximum

3.2.4.3.8.5 Receiver/Processor Assembly (R/PA)

A receiver processor shall be provided by the government. The specification referenced in Paragraph 2.1.9.2 shall be used as a guide in defining the R/PA characteristics. The R/PA shall accept commands and uploading/aiding information containing time, the orbital parameters of the Flight Segment and almanacs of the GPS Navigation Data Satellites. On intervals selected by command, the R/PA shall supply the computed position, velocity and GPS system time for the Flight Segment for down link transmission on the spacecraft telemetry. The R/PA shall receive the navigation signals transmitted by the NDS and provide three-dimensional position and velocity information and time. The R/PA shall perform the following functions:

- o Accepts uploading of time, S/C orbital parameters and one or more NDS almanacs. The R/PA shall be capable of operations with one NDS almanac.
- o Detects and acquires the best geometrically situated navigation signals generated by the NDS transmitter.
- o Tracks the acquired signals
- o Discriminates against multipath
- o Provides resistance to unintentional interference
- o Extracts the data

- o Measures and outputs the pseudo-range and delta-pseudo-range information
- o Computes and outputs the spacecraft three-dimensional position and velocity and GPS system time. In the absence of NDS signals, there shall be an extrapolation of the last measured spacecraft position and velocity.
- o Maintain GPS system time, Time Code Generator Time and almanac memory in a low power standby mode.

The Receiver Processor shall consist of the following major functional elements:

- o Receiver
- o Processor/Software
- o Synthesizer
- o Time Code Generator
- o Power Supply

3.2.4.3.8.5.1 Receiver

The receiver, under processor control, shall accept and operate on the output of the antenna/preamplifier assembly. The receiver shall include two identical tracking channels which can be used interchangeable either one at a time, or simultaneously making independent measurements.

The receiver outputs the required time, pseudo-range, delta-pseudo-range pairs (L1 and L2), and system data extracted from navigation signals to the processor to sequence its operations and aid in the selection and acquisition of the available navigation signals.

One channel (selectable by command) the the parallel receiver will make sequential L1 and L2 measurements (in that order) to each NDS up to a maximum of four. The secondary channel will operate in one of three modes; search and acquisition, simultaneous L2 and L1 measurements (in that order) to all visible NDS's up to a maximum of six. Failure of one

receiver channel shall not prevent operation of the surviving channel in the sequential mode.

3.2.4.3.8.5.2 Processor

The processor shall perform the following operations:

- o Accept and store almanacs for the Flight Segment and up to 24 NDS.
- o Accept a Time Code Generator (TCG) clock setting command.
- o Accept, store, and output on command TCG readings.
- o Determine which NDS are within view. For more than four in view, the processor shall select the best set of 4 NDS's for navigation using an algorithm which incorporates criteria including elevation angle, Geometric Dilution of Precision, Time in view and NDS health. For each selection, estimates of pseudo-range and delta-pseudo-range shall be derived from the ephemeris to assist the receiver in acquiring the signals.
- o Output the pseudo-range and delta-pseudo-range on all satellites being tracked by the receiver and computed position, velocity, and time.
- o Compute and output on command a current estimate of the Flight Segment position and velocity using best known information. This shall be possible even with extended loss of all signals so long as the processor, TCG power, and oscillator input are continuously maintained.
- o The processor shall aid the receiver acquisition and tracking by providing frequency selection for each channel, the NDS selection and the code type to be processed. The processor shall provide pseudo-range and delta-pseudo-range to the receiver as code time and doppler offset prepositioning commands.

3.2.4.3.8.5.3 Synthesizer

The synthesizer shall accept the output of the reference oscillator and create all the necessary R/PA mixer frequencies, code rates and timing signals.

3.2.4.3.8.5.4 Time Code Generator

The R/PA shall contain a time code generator independent of GPS system time with the capability of a non-repeating readout for about 1 year. The Time Code Generator (TCG) shall have a resolution of less than 1.0 microseconds. The accuracy shall be determined by the accuracy of the reference oscillator. The TCG shall be capable of being set to the nearest second by serial upload from the ground. the TCG shall operate and accumulate time in all R/PA modes except the "power off" mode.

3.2.4.3.8.5.5 Power Supply

The power supply shall accept the Flight Segment prime power and distribute voltage and currents for R/PA operations. ON, STANDBY, TRACK, and OFF control will be by command. The power supply shall supply DC power to the reference oscillator and preamplifier. The preamp shall be continuously powered in the STANDBY mode.

3.2.4.3.9 Deleted

3.2.5 Space Vehicle Interface Requirements

3.2.5.1 Delta 3920 Launch Interfaces (all references to the Delta 3920 launch vehicle performance capability are changed to 4790 pounds).

3.2.5.1.1 Launch

The Landsat-D and D' shall be inserted into the orbit specified in Paragraph 3.1 plus injection errors by a Delta 3920 launch vehicle from the Delta Space Launch Complex at the Western Test Range (WTR). The capabilities of this launch vehicle are specified in the document identified in Paragraph 2.2.2.1.

3.2.5.1.1.1 Orbit Parameter Dispersions

- o The mean inclination of the Landsat-D orbit shall be 98.2° with a 3-sigma variation of $\pm 0.05^\circ$.
- o the mean eccentricity of the Landsat-D orbit shall be circular (i.e., 0) with a 3-sigma variation of ± 0.002 .
- o The mean semimajor axes of the Landsat-D orbit shall be 7083.46 Km with a 3-sigma variation of ± 23 Km.

3.2.5.1.2 Mechanical Interface

The mechanical Interface between the Delta launch vehicle and the Flight Segment shall be through the MMS Launch Vehicle Adaptor Fitting as specified in Paragraph 3.2.3.1.2.

3.2.5.1.3 Electrical Interface

Pre-launch electrical interface with the Flight Segment shall be through the MMS umbilical connectors as specified in the document in Paragraph 2.1.2.5.

3.2.5.1.4 Launch Support and Test Facilities

3.2.5.1.4.1 Launch Support Facility

The contractor shall specify the equipment requirements for handling and mating the Flight Segment to the launch vehicle. The contractor shall define the blockhouse space, equipment, and launch vehicle connections required to operate the Flight Segment and monitor the launch vehicle during the pre-launch and launch activities. The facility will be GFE.

3.2.5.1.4.2 Ground Station/Computer Facility

The contractor shall define the requirements of the launch site ground station and computer facility including equipment, space and environmental control. The facility will be GFE.

3.2.5.1.4.3 Flight Segment Test Facility

Suitable spacecraft test facility requirements shall be defined. These requirements shall specify high bay working area size, transporting equipment, clean room size and environment, power and pneumatic supply, propellant loading area, and limited access provision requirements. This facility will be GFE and will be located in the spin facility on VAFB.

3.2.5.1.4.4 WTR RF Link Study

The contractor shall conduct an RF link study and fabricate hardware necessary for RF transmission between the Flight Segment and the Landsat-D WTR launch site ground station. The RF communications are necessary for Flight Segment pre-launch checkouts in the Flight Segment Test Facility and on the gantry.

3.2.5.1.4.5 Pre-Launch Testing

The contractor shall provide the necessary Flight Segment testing at WTR to verify that the Flight Segment is ready for launch. The testing shall be compatible with the Delta Launch Vehicle R-day schedule.

3.2.5.2 Space Transportation System

3.2.5.2.1 Retrieval

The Flight Segment shall be designed to be retrievable by the STS. Retrievability of the Flight Segment shall be accomplished by the Flight Support System (FSS) as defined in paragraph 2.1.8.10. The Flight Segment must conform with the safety requirements and the requirements for appendage retractability and jettisoning to meet the Shuttle payload bay envelope requirements as defined in the documents specified in Paragraphs 2.1.8.1 and 2.1.8.2. (see 4.6 on STS Safety Analysis and Responsibilities).

3.2.5.2.2 Mechanical Interfaces

The mechanical interface between the STS and Flight Segment shall be through the MMS Transition-Adaptor as specified in Paragraph 3.2.3.1.1 and the Flight Segment structure shall be designed to provide support through this adaptor under the worst case STS landing conditions specified in Paragraph 2.1.8.1.

3.2.5.2.3 Electrical Interface

The STS electrical interface with the Flight Segment shall be through the MMS umbilical connector specified in the document identified in Paragraph 2.1.2.5.

3.2.6 Environmental Testing

The environmental test program is part of an overall verification effort to ensure that the Flight Segment will function successfully and thus achieve mission objectives. It includes a series of tests and analytical programs conducted to qualify the design and to provide assurance that the flight equipment is capable of performing satisfactorily under the environmental conditions to which it will be exposed. The test program shall include protoflight and flight acceptance tests at the subsystem and flight segment level. Prototype qualification of components shall also be included. A test plan shall be provided. The contractor shall list all tests to be performed.

3.2.6.1 Protoflight Design Qualification Tests

The first build flight hardware shall be tested to protoflight levels. For quasi-steady accelerations as well as sine and random vibration, the qualification test factor shall be 1.25 X flight loads (U+2 sigma) for Delta generated loads. The acoustic qualification test factor shall be 1.4 X flight levels for the Delta vehicle. Assume that the published acoustic flight levels for Delta, paragraph 2.6.6.1 shall be the baseline (i.e., 2 sigma) for applying the 1.4 qualification factor.

Note: That for component random vibration, apply the reduced qualification test factor to the g-RMS values. Protoflight temperatures will be 10 °C more severe than the worse hot and cold conditions expected during launch, orbit and retrieval. The duration of the tests, when applicable, shall be at acceptance test levels. Appropriate margins are added to all other test environments as well.

The flight segment must be designed to be launched by the Delta 3920 and retrieved from orbit by the STS. The worst case levels of Paragraph 2.1.6.1. shall be utilized in the determination of the test program and levels. Design and operational requirements of paragraph 2.1.8.1 shall be used in design and functional verification.

GSFC shall be responsible for evaluation of STS landing loads and Landsat-D structural integrity for STS retrieval landing.

Test levels and conditions applied to the flight segment shall not create an environment exceeding that allowed by the relevant MMS, MSS and TM design qualification specification in paragraphs 2.1.2.9, 2.1.4.2, and 2.1.3.1. This restriction, coupled with the guidelines of Paragraph 2.1.6.1, section 2.1.10.1, may require a unique dynamics test program to achieve full system qualification.

A full scale model may be used for the measurement of antenna patterns in lieu of the requirements of Specification GETS (ELV)-1 for patterns to be measured on the Flight Spacecraft. An antenna gimbal life test shall be performed in vacuum.

The following test and data should be provided:

- o Omni Antenna patterns with Omni's mounted on "Y" Axes
- o Include TDRS EMI Levels in Link Calculations
- o Omni patterns in Launch Configuration
- o EMI Levels in Aperture of Instruments
- o Provide 2dB, 3dB, and 4dB margin omni antenna plots
- o Provide stress analysis and conduct crack propagation experiments on TWT potting materials. Provide life expectancy data on this material.

3.2.6.2

Flight Acceptance Tests

The subsequent hardware shall be tested to worst case expected launch, orbit and retrieval environments. The flight acceptance test program and levels shall be as those defined in Paragraphs 2.1.6.1 and 2.1.8.1 with an estimated overall acoustic level of 144 dB.

3.2.7

GSE and Compatibility Tests

3.2.7.1

Flight Segment GSE Testing

Equipment shall be provided to ensure that the Flight Segment ground station equipment is operating within specifications prior to any powered Flight Segment testing. This equipment should consist of, but not be limited to items such as TM and MSS simulators, X- and Ku-bands transmitters, receiver, demodulator, signal conditioner, bit error rate detectors, etc.

Provide a GPS Engineering Model Antenna for compatibility testing at GPS contractor's facility.

3.2.7.2

STDN and TDRS Compatibility Tests

Tests shall be required at the contractor facility to ensure compatibility between the Landsat-D System and the NASA Spaceflight Tracking and Data Network (STDN) including the TDRS. A NASA compatibility van shall be made available along with operating personnel to aid in the performance of these tests. The van contains receivers, transmitters, command encoders, data handling equipment, and a ranging system, all identical to those used in the GSTDN to support the C&DH communication links. The van shall be used to test Landsat-D compatibility with STDN. These tests should be conducted, as much as possible, in parallel with other Flight Segment testing. The duration of time required for these tests shall be determined by the contractor. Test procedures and a final report shall be generated by GSFC personnel after initial consultation with the contractor. MMS ground support equipment defined in paragraph 2.1.2.15 shall be provided by GSFC.

3.2.7.3

A programmable data formatter and a 56 kbps data circuit will be provided by NASA to the contractor for transmission of telemetry data from the flight segment at the contractor's facility to the OCC at the GSFC for flight segment/ground segment compatibility tests.

3.3 MISSION OPERATIONAL REQUIREMENTS

3.3.1 Landsat-D Data Acquisition

3.3.1.1 Wideband Data Communication - There shall be three methods of acquiring wide band data. One primary means of acquiring NASA instrument data (TM and MSS) shall be the acquisition of worldwide data through the TDRSS ground terminal at White Sands, New Mexico, where these data shall be recorded at their real-time rates. At White Sands, the recorded data shall be relayed via a Domsat link to the GSFC at an appropriate data rate to be ultimately recorded at the DMS facility. Relay rates to the DMS are defined in paragraph 3.4.3.1.1.1.

A second means of acquiring TM and MSS data shall be by direct transmission to the TGS via the X- and/or S-Band links. These data will not be recorded at the TGS but will be routed directly to the DMS for recording at real-time rates.

A third means of acquiring MSS data shall be by direct S-Band transmission to GDS and ULA with relay to the Domsat Interface Facility (DIF) located at GSFC Bldg. 23 via DOMSAT. The MSS data are captured by DIF on 14 track tape and provided to DMS.

3.3.2 Operations Control Center

3.3.2.1 General - The OCC is the focal point for all Landsat flight activities and provides control of the spacecraft and the orbital payload and GPS activities required to satisfy the overall mission objectives. For the purpose of this specification, the MMS is considered as part of the spacecraft and will be controlled within the OCC. The OCC shall be operated on a 24-hour-per-day, 7-day-per-week basis and its activities will be geared toward the operational timelines dictated by the flight segment, RF communications coverage capability, and the availability of the Domsat transmission links.

It will be the overall responsibility of the OCC to plan, schedule, and operate the two flight segments within their capabilities to acquire the data necessary to satisfy the Landsat mission objectives while both flight segments are simultaneously in orbit. This responsibility includes the scheduling and controlling of the necessary support of the STDN and Domsat links and providing the necessary data management reporting functions from the original planning stage until receipt of data at the GSFC.

The design of the OCC shall be such as to preclude any single point failure that will prevent either commands being transmitted or flight segment telemetry being displayed for a single flight segment.

The interfaces identified in Figure 3.3.2.1-1 and in the following paragraphs shall be considered in the design of the OCC to satisfy the functional requirements. In addition, the OCC design concept shall relate to the pre-launch, launch, and in-orbit operations.

3.3.2.2 OCC Function - Within the Operations Control Center, three primary functions are performed.

3.3.2.2.1 Mission Operations - The OCC shall provide mission support for the launch and operations of both flight segments. This function shall include a system that will permit mission management personnel ready access to flight segment control related information, software, and procedures for long range and day-to-day flight segment operations planning, scheduling, and mission performance evaluation for each spacecraft.

The following responsibilities will be associated with the performance of the mission management function:

- o Receive image coverage requirements
- o Schedule required STDN, TDRSS and Domsat link availability
- o Manage the record and playback capabilities of the narrow band tape recorders on Landsat-D and D'

- o Deleted
- o Schedule required ground communication links (data and voice) including scheduling building 23 DIF support
- o Generate the Host Vehicle Almanac for the GPS
- o Maintain up-to-date flight segment capabilities (power, health, etc.)
- o Distribute time signals to Ground Segment facilities including TGS
- o Prepare predicted daily and long range activity lists
- o Plan and execute flight segment orbit change maneuvers
- o Prepare daily and summary data management reports
- o Generate star catalog and ephemeris data updates for the on-board attitude processor
- o Generate daily payload scheduling messages in support of foreign ground receiving stations
- o Maintain contingency plans for abnormal situations

The Operations Control Center will receive at an external interface the following:

- o Landsat and TDRS-E and TDRS-W Ephemeris Representation Data
- o NOAA cloud cover forecasts
- o USNO Pole Position Data
- o GSFC orbit determination ephemeris for both predicted spacecraft location and ground receiving station acquisition as required
- o NSWC NDS almanac data
- o UTC-GPS time difference
- o Orbit adjust requirements
- o Direction angles from the flight segment to the TDRS Satellites
- o Flight Segment telemetry data
- o STDN/NASCOM schedules
- o NASA time signals

3.3.2.2.2

Flight Operations Control - This segment of the OCC shall have the necessary hardware and software to perform the following functions:

- o Load and verify OBC and GPS R&PA programs
- o Command management, generation, transmission, and verification of all flight segment commands and on-board computer (OBC and GPS RPA) updates
- o Provide a "quick-look" capability to allow the display of sampled instrument data
- o Provide ground communications configuration control and performance status determination
- o Real-time monitoring of flight segment health and payload operations

- o Flight segment RF communications system operation and control
- o Telemetry data processing and status display
- o GPS operation and status determination including initialization, and modification and verification of data base constants
- o Flight dynamics assessment and control (station keeping and attitude control)
- o Verify GPS ephemeris data
- o Extract and record all GPS data and OBC ephemeris data and provide the recordings for orbit determination and GPS evaluation
- o Extract, store, and electronically provide to DMS Telemetry and Ephemeris data required for MSS data processing
- o Receive, process and record TM PCD. Provide the recordings to DMS and provide a directory electronically to DMS

3.3.2.2.3

Flight Segment and Instrument Performance Evaluation - The OCC shall have the capability to perform in-depth engineering evaluation for both flight segments in an off-line capacity for, but not limited to, the following:

- o GPS data and OBC ephemeris data
- o MSS telemetry and ephemeris data
- o TM payload correction data
- o Subsystem trend analysis
- o Problem investigation
- o Flight segment performance report generation
- o Instrument "quick-look" analysis
- o Verification of data reception including MSS and TM data

3.3.2.3 OCC Interfaces

3.3.2.3.1 Telemetry - The OCC design shall consider the telemetry interface requirements and necessary monitoring and display mechanisms compatible with the flight segment design as specified in Paragraph 3.2.3.2 of this document. The OCC design shall be such that no single point failure will prevent monitoring a single flight segment status on a 24 hour basis. The capability to monitor dual flight segment status on a 24 hour basis shall be provided. In addition to in-orbit monitoring, considerations shall be given to pre-launch and ascent status monitoring as required and as compatible with the mission operations concepts and launch vehicle and flight segment design constraints during these phases.

3.3.2.3.2 Commands - The OCC design shall consider command interface requirements during deployment, and in-orbit flight segment operations. Command interface responsibility shall be defined regarding command generation, regeneration and reissuance. As applicable, considerations shall be given to safeguarding hazardous and critical commands during the retrieval phase. The OCC design shall be such that a command history log shall be maintained and readily accessible for use as required. The OCC command design requirements shall be compatible with the MMS error detection codes. Command verification or command rejection shall be traceable through the data handling system. The OCC design shall be such that no single point failure will prevent commands being generated and transmitted for a single flight segment.

3.3.2.3.3 Operations Coordination - The contractor shall identify and specify operations coordination communications requirements and interfaces. These requirements must include voice coordination between OCC and the launch site during launch and pre-launch activities, between OCC and STDN stations, including the local user stations receiving direct read-out data and the TDRSS ground terminal at White Sands, New Mexico. Requirements for voice coordination shall be defined between OCC and other GSFC operations including the DMS recording facility, the DMS, and the GSFC orbit support computing facility.

3.3.2.3.4 Delta 3920 Support Data - The contractor shall identify and define the requirements for, and interfaces of, data flow between the OCC and the WTR launch site during the pre-launch and launch activities. This definition shall consider the link and data requirements necessary to verify proper flight segment configuration, separation, and deployment in-orbit for both Landsat-D and D'.

3.3.2.3.5 Orbit Computations Support - Tracking and orbit computational data will be required at the OCC during the Landsat-D mission. The contractor shall define the interfaces required to assure timely acquisition of these data by the OCC. The Flight Segment will have two separate in-orbit tracking capabilities. The first will be the standard GSFC ranging system which will be tracked through the GSTDN/TDRSS and the tracking data will be sent to the GSFC Operations Support Computing Facility for computation of the necessary orbital parameters. The uncertainty for both position and velocity are shown below:

PREDICTION UNCERTAINTY (1-SIGMA)

Days From Tracking Cutoff	1	2	3
Position	250 m	500 m	1000 m
Velocity	25 cm/sec	65 cm/sec	120 cm/sec

NOTE: Radial component of velocity and along-track component of position represent 99% of the above uncertainties.

A second system, the Global Positioning System (GPS), will also be used. It is anticipated that the GPS system, after initial checkout and calibration, will be the primary system of providing accurate tracking information. It shall be the responsibility of the mission contractor to determine the tracking accuracies required and propose a system to utilize these data for flight segment time updates, attitude control updates, mission operation planning, flight maneuver determination, and to provide accurate ephemeris information to the DMS.

3.3.2.3.6 Deleted

- 3.3.2.3.7 OCC/DMS Data Exchange - The exchange of data between the OCC and DMS shall be accomplished electronically except for TM PCD.
- 3.3.2.3.8 Data Communications - The OCC design shall provide data communications interfaces between NASCOM and the OCC. The contractor shall define the interfaces required for the transmission and reception of command, telemetry, scheduling, and status data. These interfaces are to be compatible with the NASCOM telecommunications system as described in the document identified in Paragraph 2.2.2.12.
- 3.3.2.3.9 NCC Interface - The OCC design shall provide electronic scheduling, control, and status interfaces between the Network Control Center and the OCC. The contractor shall define the interfaces required for the exchange of scheduling, control, and status data. These interfaces are to be compatible with the protocol as described in the document identified in 2.2.2.13. In addition the contractor must integrate the GFE mission planning terminals into the OCC design.
- 3.3.2.4 Testing and Simulation - The OCC shall have the capability of performing a variety of ~~the~~ flight segment and support element test and simulation functions in concert with other elements of the Landsat-D and D' system. This capability will be utilized for system checkout prior to launch and for checkout of OCC modifications made during in-flight operations.

The OCC shall contain, as an integral part, a dynamic spacecraft simulator capable of interacting with the OCC for use during simulations, to support reprogramming of the on-board computer (OBC), and to verify changes in the OCC hardware and/or software subsystems prior to in-flight use with the flight segment. This simulator shall have as a minimum the following capabilities:

- o Be capable of generating dynamic flight segment telemetry data
- o Respond to commands with changes in the telemetry data

- o Reprogramming the Flight Segment OBC
- o Contain a model of the OBC for purpose of receiving and verifying command memory loads and for reprogramming and verifying OBC software
- o Contain a dynamic model of the attitude control system, the TDRS antenna control system, and the solar array drive control system

The testing and simulation capabilities required of the OCC fall into four categories: engineering data flow tests, simulations, operation readiness verification tests, and post launch modification testing. These will be further specified in the following subsections.

3.3.2.4.1

Engineering Data Flow Tests - The OCC shall provide the capability to perform the following functions for both Landsats D and D':

- o Proof test all hardware and software systems needed to support Landsat operations. This involves the following support functions: OCC, attitude determination and control, orbit determination, Data Management System, Transportable Ground station, GSTDN, TDRSS, DOMSAT, command transmission and reception, and data transmission circuits. These functions do not necessarily have to be tested simultaneously; they may be tested interface by interface. End-to-end data flow tests will be conducted to ensure continuity between support elements of the ground systems.
- o Training personnel in Landsat operations

The engineering data flow tests shall be an integral part of Landsat system development. During these tests, it shall be necessary that a flight segment simulator be used. The major difference between engineering data flow tests and simulation testing is that no attempt is made to adhere to an operational time line during engineering data flow tests.

3.3.2.4.2

Simulations - The OCC shall provide the capability to perform Landsat-D and D' operations simulations that include all elements of the Landsat system. This will include all interfaces with OCC (e.g., STDN, TDRSS, DOMSAT, etc.). During these simulations, the flight segment's simulator shall be used where necessary to simulate the total Landsat system and demonstrate performance within realistic timelines. These simulations shall also demonstrate that no single-point failure exists preventing either commands being transmitted or flight segment telemetry being displayed.

The simulation capabilities provided by the OCC shall include but not necessarily be limited to the following:

- o Exercise the entire Landsat system end-to-end in real-time
- o Develop operational time lines
- o Exercise nominal and contingency mission procedures
- o Provide training for personnel under realistic operational conditions
- o Optimize the Flight Segment and ground system operational interfaces
- o Demonstrate Landsat system readiness

The types of simulations that shall be conducted are as follows:

- o Terminal count through ascent
- o Orbital operations (Flight Segment checkout and instrument operations)
- o Orbital insertion operations
- o Contingency plan simulations as developed under Paragraph 3.3.2.2.1 of this specification

- 3.3.2.4.3 Operational Readiness Verification Test - The OCC shall provide the capability to perform the Landsat-D Operational Readiness Verification Test. This test shall consist of an end-to-end verification of the entire Landsat-D system including the launch vehicle/Flight Segment configuration prior to launch. The contractor shall define requirements of this test to include the Flight Segment (including payload data) and all elements of the OCC. This test will be compatible with and may be run in conjunction with a similar verification test of the DMS. A similar test will be required prior to the launch of D'.
- 3.3.2.4.4 OCC Self Test Capabilities - The OCC shall have the capability to completely verify compatibility and integrity of all subsystems during both pre-flight and in-flight phases of the mission. This self test capability shall utilize the flight segment simulator where appropriate to check out such modifications prior to actual flight use. These tests will include but not be limited to the following:
- o Reprogramming flight segment on-board computer (OBC) 18 56
 - o Software and hardware modification within the OCC
 - o Diagnostic tests for rapid fault detection and isolation
- 3.3.2.5 OCC Operation - The contractor shall prepare and deliver a manpower staffing plan for OCC functions.
- 3.3.2.6 OCC Site and Support Facilities - The OCC shall be designed and implemented to operate in facilities as described in Paragraph 3.4.2.5 of this document except that the total floor space available to the OCC facility will be 557 square meters (6000 square feet). The contractor shall meet all the requirements of Paragraph 3.4.2.5 for the OCC facility.

3.3.3

Landsat-D Transportable Ground Station (TGS)

The TGS shall have X-band and S-band capability to receive direct transmissions of MSS and TM data. These X-band and S-band facilities must allow the Landsat-D system to meet the communications requirements specified in Paragraph 3.2.4.3.1 and have minimum ground station parameters as specified in Appendix A. OCC interface with the TGS data will be via a demultiplexer at the TGS/DMS interface (see Figure 3.3.2.1-1).

3.4 - DATA MANAGEMENT SYSTEM (DMS) REQUIREMENTS

3.4.1

Introduction - The Data Management System (DMS) shall be the ground system used to convert the Landsat-D and D' data into specific data products that meet the systems objectives and are acceptable to the data users. The DMS will be located at Goddard Space Flight Center (GSFC), Greenbelt, Maryland.

The DMS shall be designed, configured, implemented, and operated in a manner to meet, initially, the specified data processing requirements of a Landsat-D mission. Subsequently, the DMS must meet the specified data processing requirements of the combined Landsat-D and Landsat-D' missions.

By July 1983, in addition to the operational MSS capability required, the DMS must have in place an R&D capability for TM. The purpose of the TM R&D capability is to characterize the TM Sensor performance and benchmark TM system performance and throughput capacity. This is to specify system hardware and software requirements for an operational TM image processing system. The TM R&D capability provided by July 1983, will include a priori geometric correction for uncompensated spacecraft momentum effects.

The DMS shall be designed, manufactured and operated to produce magnetic tape and photographic film products in a manner that will not degrade the spectral, radiometric, and geometric properties of the TM and the MSS, specified in Sections 2.1.3.2 and 2.1.4.1, respectively.

The DMS shall perform but not be limited to the following functions:

1. Capture input data stream at up to real-time rates for TM, and up to three times real-time rates for MSS.
2. Provide for automated/semi-automated detection of cloud cover in the images.
3. Provide for application of TM and MSS radiometric corrections to each pixel.
4. Generate from ancillary data sources such as on-board navigation and attitude data, ephemeris, and ground control points, pixel by pixel geometric corrections.
5. Provide for data formatting and other annotation as necessary for image identification.
6. Provide for application of various resampling and projection geometric corrections.
7. Generate archival products, specified user products, and quality assurance products.
8. Maintain process control through automated/semiautomated data and data base management.
9. Provide for automated/semiautomated selection of MSS or TM images or TM subimages (quadrants) for processing and/or product generation.

10. Maintain production status data such as records location, data catalogs, processing and production statistics in an on-line data base management system.

11. Provide the necessary data base to support dual spacecraft operations.

12. Deleted

13. Provide DMS Quality Assessment test data, capability, and procedures.

14. Provide MSS and TM processing separability.

3.4.2

General Requirements

3.4.2.1

Input - Input data to the DMS will consist of:

- o Image data
 - Landsat-D - Multispectral Scanner and Thematic Mapper data
 - Landsat-D' - Multispectral Scanner and Thematic Mapper
- o Ancillary data
 - Landsat-D - such as ephemeris, attitude, payload correction data, correction parameters, calibration and ground control point data
 - Landsat-D' - such as ephemeris, attitude, payload correction data, correction parameters, calibration and ground control point data
- o Process control data to initiate, control, monitor, and revise production operations as they are carried out on the various processes

3.4.2.2

Output - Output data from the DMS will consist of:

- o Processed image data
 - Landsat-D - MSS
 - Beginning July 1983 - MSS and TM
- o Ancillary data such as correction parameters, quality data, and calibration data
- o Annotation data such as tick mark locations and image frame identification
- o Process control data such as operator messages and work orders
- o Production data such as daily processing and performance statistics, quality control reports, management reports, and data catalogs

3.4.2.3

The MSS DMS shall be designed and configured in a manner such that failures do not prevent the MSS DMS from achieving the required turnaround time. Full MSS system operation (full processing capability as defined in 3.4.4.1.4) shall be achieved within 85% of the scheduled two shift per day operation period (16 hours per day) averaged over 10 contiguous days. Conformance to this requirement is computed daily based on a 10 day interval ending that day.

The R&D TM DMS shall demonstrate the capability to achieve full system operation (full processing capability as defined in 3.4.4.1.4) within 85% of a single shift 8 hour day.

3.4.2.4

DMS Device Compatibility - There is a requirement to maintain certain existing interfaces with respect to the processing and distribution of Landsat-D MSS data to the EROS Data Center (EDC) and also to maintain compatibility with the high data rate recording devices which will record the Landsat-D TM/MSS data at the TDRSS ground terminal at White Sands. To maintain the required compatibilities, two different types of High Density Tape (HDT) Recorders will be required.

3.4.2.4.1

High data rate recorders capable of recording and reproducing TM/MSS data at rates up to 85 Mbits/Sec - The HDT recorders which will be used to play back video tapes that have been recorded at the TDRSS downlink at White Sands must be compatible with the 42-track recorder specified in the document in paragraph 2.1.7.1. All high data rate recorders shall provide a total bit error rate of 10^{-8} or less using standard non-certified GSA Type 79A magnetic tape.

3.4.2.4.2

Low data rate recorders capable of recording and reproducing Landsat-D MSS data at rates up to 20 Mbits/Sec - The HDT recorders used to record MSS image data HDTs for distribution to the EROS Data Center (EDC) must be compatible with the 14-track recorders specified in the document in paragraph 2.1.7.2. All low data rate recorders shall provide a total bit error rate of 10^{-8} or less using standard non-certified GSA type 79A magnetic tape.

3.4.2.5

DMS Site and Support Facilities - The system shall be designed to be implemented in a typical computer system environment. This means that no special generators or commercially unavailable power sources, air conditioning, humidity control, and air contamination control shall be required to ensure operability of the DMS.

Facility integration and installation requirements and plans shall be prepared by the mission contractor.

Facility preparation will be the responsibility of GSFC but providing and meeting the requirements for that facility, within the constraints described below, will be the responsibility of the mission contractor. The mission contractor shall identify the facilities required in the form of a facility requirements document.

3.4.2.5.1

Floor Space - The amount of total floor space available for the DMS facility will be 2415 sq. meters (25,000 square feet). The raised floor will be designed to nominally support 1217 kg/sq. meter (250 lbs/sq. feet) first floor and 730 kg/sq. meter (150 lbs/sq. foot) second floor. Minimum clearance beneath the raised floor is 30 cm (12 in.). This total area includes equipment, office, and support areas.

3.4.2.5.2 Power - The DMS shall use a primary power source at 208 volts, 3 phase, 60 hertz or 120 volts, single phase, 60 hertz as the primary power source. Long term power variations of +5 percent and -10 percent shall be tolerated by the DMS. Each power entry into the DMS or its subsystem shall be electrically protected with circuit breakers and/or fuses adequate for the expected loads including blowers and fans. The DMS power requirements shall be identified by the mission contractor.

There are not provisions at the GSFC for an uninterruptable power supply; however, the mission contractor shall provide reasonable safeguards to protect the DMS from power surges and power outages (i.e., Transient Line Filters, Data Base Protection and Recovery Techniques, etc).

3.4.2.5.3 Air Conditioning - The following environmental conditions will be maintained within the facility where the DMS is to be installed.

	<u>Operating</u>	<u>Nonoperating</u>
Relative Humidity	40% - 60%	30% - 85%
Temperature	20°C - 25°C	10°C - 35°C
Gradient	1°C per hour 2% R.H. per hour	2°C per hour 4% R.H. per hour

The DMS air conditioning requirements shall be identified by the mission contractor.

3.4.3 Functional Requirements - This section specifies the input and output data accepted and produced by the DMS, processing functions, and data base management requirements. Operational considerations are also discussed.

3.4.3.1 Data Handling Functions

3.4.3.1.1 Input Data

3.4.3.1.1.1

Image Data - Flight Segment instrument data input to the DMS will be received both electronically and on tape. The DMS must be capable of capturing simultaneously, three electronically-received MSS and TM data streams.

The DMS must receive or capture, on high density tape MSS and TM input data from the following sources and specified bit rates:

<u>Source</u>	<u>Landsat-D & D'</u>	
	<u>MSS bit rate</u>	<u>TM bit rate</u>
<u>TDRSS</u>		
shipped tape via DOMSAT (electronic)	NA	NA
	Real Time	1/2 X Real Time
	2 X Real Time	-
	3 X Real Time	-
<u>GSTDN</u>		
shipped tape Tape via DIF	NA	-
	NA	-
<u>TRANSPORTABLE GROUND STATION</u>		
via direct link (electronics)	Real Time	Real Time

The DMS shall be capable of reading for further processing, as may be required, any of the above tapes or any image tape product, either HDT or computer compatible tape, that may be generated by the DMS as the result of any processing operation.

3.4.3.1.1.2

Ancillary Data - Ancillary data input to the DMS will consist principally of ephemeris data, attitude data, payload correction data calibration data, and control point data. The correction data may be those generated by the DMS as part of production processing.

Ancillary data may be provided to the DMS via:

- o Computer-to-computer data link
- o CCT input
- o Non-image subsets of the input TM and MSS data streams
- o An interactive control point station
- o A non-image subset of DMS produced tapes (HDT or CCT)
- o Interactive DMS Terminal
- o Punched card input

3.4.3.1.1.3

Process Control Data - Process control data input to the DMS will consist of processing descriptions, processing instructions, control and operational commands, and any other data related to system and process control. Process control data may be provided via: -

- o Computer-to-computer data link
- o A subset of an ancillary data input (HDT or CCT)
- o A non-image data subset of DMS produced image tapes (HDT or CCT)
- o Interactive DMS terminal (operator input)
- o Punched card input

3.4.3.1.1.4

Data Base Updates - Data base update input to the DMS will consist of data required to keep agency or user files current, track process control, product distribution, etc. Update data will be provided on CCT, punched cards, interactive terminal, or computer-to-computer data link.

3.4.3.1.2 Output Data - The DMS shall generate the following output data:

3.4.3.1.2.1 Image Data - Flight Segment instrument data shall be output by the DMS in the following manner:

- o Recorded on High Density Tape
- o Recorded on Computer Compatible Tape
- o Via a DOMSAT uplink ground terminal, either direct or from HDT
- o On 241 mm (9 1/2 in.) latent film
- o On 70 mm latent film

3.4.3.1.2.2 Ancillary Data - Ancillary data output by the DMS will consist of data/parameters related to radiometric processing and quality and data/parameters related to geometric correction and quality as well as image data quality information and HDT and film inventory information.

Ancillary data will generally be output either as a non-image subset of DMS produced image tape products or on a separate Computer Compatible Tape (CCT). The government shall provide the capability to transmit HDT inventory information to Agency users thru the current GSFC bldg. 23 interface.

3.4.3.1.2.3 Annotation Data - Annotation data output by the DMS will consist of output image tick mark locations and image/scene identification.

Annotation data will generally be provided as a non-image subset on DMS produced image tapes or annotated on DMS produced film products.

3.4.3.1.2.4 Process Control Data - Process control data output by the DMS will consist of messages for the system operator.

Process control data will be provided as an alphanumeric CRT display on an interactive terminal. All messages to the operator and all operator responses shall be logged by the DMS and output as hardcopy at convenient intervals. A summary report shall be provided at the conclusion of each process or run.

Process control data also include the generation of work orders to define and control the execution of processes that are external to the DMS, such as photo lab processing and product distribution. These data shall be in the form of hard copy and terminal displays.

3.4.3.1.2.5

Production Data - Production data output by the DMS will consist of those data necessary to provide a complete accounting of every production run or intermediate process performed by the DMS. The DMS shall also generate management reports, coverage catalogs, and user related data.

The capability to generate catalogs of available imagery sorted both by geographic location (lat./long. and/or WRS path/row), by spacecraft, and chronologically (scene ID), for both TM and MSS data, shall be provided. It shall also be possible to query the data base of available imagery, either interactively from a DMS terminal or in a batch mode, and request available coverage sorted geographically or by scene ID and further sorted according to time period, acceptable cloud cover or scene quality.

The operational nature of the MSS, and the initial R&D environment of the TM require that the DMS integrate Landsat-D and D' MSS processing, and separate TM processing.

The DMS data base of available imagery must include all image data processed over a 3 year period beginning with the launch of the Landsat-D mission and includes both MSS and TM acquisitions. Capability to expand the data base to support an additional 2 year mission lifetime is also required.

Production data will be provided on CCT, interactive DMS terminal, and/or as hard copy as required. Data quality statistics will also be included as non-image subsets of DMS produced image tapes (HDT or CCT).

3.4.3.2 Data Processing Functions - The DMS shall be capable of performing the operations specified in the following paragraphs on the input data either collectively or selectively as requested by program or operator.

3.4.3.2.1 Image Ingest - The DMS shall accommodate the following input functions.

3.4.3.2.1.1 Decommutation - The DMS shall decommutate and/or demultiplex the TM/MSS data stream whenever necessary to facilitate processing.

3.4.3.2.1.2 Deleted

3.4.3.2.2 Operational Quality Assurance

An Operational Quality Assurance system will be provided which contains as a minimum the following capability.

3.4.3.2.2.1 Line Tests will be implemented for discrete processes at the system level and at the major subsystem/major element level. These tests will be capable of being run as frequently as a shift basis to verify operational readiness. Line tests shall include the capability of being chained to verify the end to end system performance. Successful completion of Line Tests shall ensure that the element or process tested is ready to support production.

Input data required by the line tests shall be provided. The capability to regenerate input data shall also be provided.

3.4.3.2.2.2 In-Process Production Quality Assurance will be implemented on each subsystem process and/or element, if applicable, to measure and report on the performance of the subsystem and quality of the inputs, intermediate operations and output products. The DMS shall identify poor or unacceptable input data. Data shall be assessed on a scan line (or detector) basis. Scan line data shall be appropriately flagged to identify the deviant condition encountered. Automatic system response shall be included for certain error conditions such as:

- o Insert flywheel time for known bad time
- o Substitute last known good data for loss of scan line data or smoothed data for loss of telemetry data which may be required for geometric or radiometric correction processes
- o Determine threshold for bit errors for operator alert
- o Determine thresholds for "normal" detector performance for operator alert
- o Skip bad data on a scene basis without aborting the process

Attendant data quality statistics shall be compiled by this function and output as part of the DMS production data.

3.4.3.2.2.3 Offline Quality Assurance will be implemented to routinely verify conformance of intermediate and final outputs to specifications. A statistical sampling approach will be allowed provided a data rejection rate of 5 percent or less is achieved.

Automated capability to periodically measure, analyze, recompute and update Mirror Velocity Profiles for MSS and TM shall be included. The final outputs will be revised mirror velocity profiles ready for loading into the DMS.

Capability to verify the format and range or limit check the contents of input data received from outside sources shall be provided.

The support system to measure sensor and Landsat system performance and routinely report on the performance shall be provided.

The support system to measure the accuracy of the radiometric calibration computed and applied to the imagery and prepare any required updates to calibration constants within the system shall be provided.

3.4.3.2.3

Cloud Cover Assessment - A cloud cover assessment for each nominal WRS frame of both MSS and TM data shall be made by the DMS and in the case of TM before extensive processing of the data is started.

Cloud cover assessment shall be performed on-line and cause no reduction in system throughput. Each TM image shall be subdivided into quadrants (fixed 1/4 subimages) and each quadrant individually assessed for percent of cloud cover. For TM imagery, the percent cloud cover is maintained within the DMS files, in catalogs, etc., on a quadrant basis. For MSS data, percent cloud cover is maintained within the system on a full frame basis only.

The mission contractor shall provide a cloud cover assessment implementation which provides, as a minimum:

- o The proportion of a TM quadrant covered by clouds to within 10 percent by automatic means.
- o The proportion of an MSS full frame covered by clouds to within 10 percent by manual means.

3.4.3.2.4

Quality Assurance Film Generation - The DMS shall have the capability of exposing 70 mm and 241 mm latent film masters.

MSS--70 mm film shall be produced for all MSS scenes processed to archival HDT. Selected MSS scenes shall be produced on 241 mm film for more detailed system performance evaluation and to support isolation of problems.

TM beginning July 1983 70 mm film shall be produced for all TM scenes processed to archival HDT. Selected TM scenes shall be produced on 241 mm film for more detailed system performance evaluation, to support isolation of problems, and limited TM film product generation.

All TM 70 mm film masters shall have a grid which identifies the four image quadrants which have been cloud cover assessed.

At least the following shall be recorded on 70 mm film:

One MSS band selectable from any of the four available.

Two TM bands selectable from any of the seven available.

Nominal WRS framing for this function shall agree with that of the cloud cover assessment function.

The data exposed to 70 mm film shall be corrected for detector offsets, aspect ratio, earth rotation, and shall be annotated for image frame identification (i.e., satellite, location (WRS path/row), sensor, band, time of acquisition, etc.).

Performance requirements for the 70 mm film recorder are given in the document in Para. 2.1.7.6.

All film processing services will be provided external to DMS. However, the DMS must provide work orders and tracking of the requested photographic services. The latent film produced by the DMS shall be processable within existing GSFC Image Processing Facility photo facilities.

- 3.4.3.2.5 On-Line Display - The DMS shall provide an on-line black and white display to allow the selective examination of either TM or MSS imagery. Imagery displayed shall be full frame (nominal WRS framing), at a reduced resolution of (approximately) 512 picture elements by 512 lines with at least 16 levels of contrast. It shall be possible to select any sensor band for display. Any frame displayed may be "frozen" or held on the CRT for a minimum of 5 minutes without a significant loss of contrast.
- 3.4.3.2.6 Reformatting - The DMS shall provide the capability to reformat TM data into either a Band Interleaved by Line (BIL) format or a Band Sequential (BSQ) format. MSS data is output in a BSQ format only.
- 3.4.3.2.7 Editing - The DMS shall provide the capability to select data for certain processing functions or for reprocessing. Examples of data editing are:
- Selecting scenes from the partially processed MSS HDT master from which to generate CCT's and/or 241 mm film imagery for quality assessment purposes.
 - Selecting individual scenes, either MSS or TM, for reprocessing because the original process did not produce data of acceptable quality. This selection would probably be based upon failure to achieve some predefined data quality criteria because of device malfunction or process anomaly.
 - Selecting TM scenes from the (partially processed) archive from which to generate partially and/or fully processed imagery for distribution to users. Criteria upon which to base this selection could include time of acquisition, area, user requests/user priorities, image quality, percent cloud cover, etc.

The definition, implementation, and tracking of the editing function is a major element of the DMS data base management system (see Section 3.4.3.4). The mission contractor will be responsible for defining the precise editing and data selection functions their particular DMS configuration and processing scenarios may require.

3.4.3.2.8

Radiometric Correction - The DMS shall be capable of performing complete radiometric corrections on the raw input data based upon detector calibration data, image contents (histograms), or both, in accordance with mission contractor prescribed algorithms. Radiometric correction will be applied to each pixel corresponding to an individual detector in a manner that is independent for each detector (scan line) on each sensor (TM or MSS). In other words, this means that a radiometric correction procedure must be devised which can be unique to each detector employed in the TM or MSS. This function includes both the computation of correction values as well as their application to the data.

It shall be the responsibility of the mission contractor to analyze the radiometric performance of both the TM and MSS instruments both prelaunch and postlaunch and develop/modify the radiometric correction algorithms as required to meet the specified performance requirements (see section 3.4.4.2.1).

3.4.3.2.9

Geometric Correction - The DMS shall be capable of performing complete geometric corrections on the data, both MSS & TM. In general, this includes all necessary operations on the data to remove (or compensate for) geometric distortions imparted to the data by the sensor scanning mechanism, spacecraft attitude, altitude, velocity and position variation, earth rotation, and sensor detector commutation and offsets. Provision shall be included to add corrections that may be necessary to correct for any uncompensated spacecraft momentum effects. No correction for surface effects (terrain relief compensation) will be required with the exception that the elevation of Geodetic Control Points (GCPs) must be considered in the determination of geometric error models.

The DMS shall be capable of utilizing ephemeris data from either the on-board GPS or from the Operations Support Computing Division (OSCD) at the GSFC.

The performance of the geometric correction function shall be accomplished in two distinct steps. The first step is the computation of geometric correction coefficients and sets of grid point correspondences (i.e., an interpolation grid or grids corresponding to a specified map projection) by employing spacecraft and sensor performance data and geodetic control points (if available). The second is the application of the geometric correction function to the data.

The geometric correction function shall include the capability to refine spacecraft platform orientation (i.e., reduce uncertainties in platform pointing angles) by employing geodetic control points distributed over continuous swaths of input data.

In the absence of geodetic control, correction coefficients shall be computed on the basis of the available parameters. Geometric correction shall be performed with reference to one of three map projections:

- o Universal Transverse Mercator (UTM)
- o Space Oblique Mercator (SOM)
- o Deleted
- o Polar Stereographic (PS)

This requires that correction coefficients and corresponding interpolation grids be computed for two of the above projections (UTM and PS are mutually exclusive) and carried with the archival data.

3.4.3.2.10

Geodetic Control Points (GCP) - As part of the GCP application to the geometric correction function, the DMS shall have the capability to extract suitable control points from the data, both TM and MSS, and create a reference library of control points (geodetic or relative) to be used for correction and/or temporal registration of images collected over the sensor life-time.

This function shall include the implementation of an interactive control point library building system on the DMS. Control points will be identified and initially selected from the imagery and entered into the DMS, along with control point descriptor information, via this station. The DMS shall include capability to select candidate GCP's from maps and photographic imagery and to update the library (add or delete GCP, modify coordinates, etc.). The system shall include the capability to use, or selectively use, the existing Landsat 2/3 GCP Library.

- 3.4.3.2.11 Resampling - The DMS shall have the capability to resample image data as part of the geometric correction function. At least two resampling methods shall be implemented: nearest neighbor and cubic convolution (4 x 4 points minimum).
- 3.4.3.2.12 Tick Marks - The DMS shall compute tick mark locations for all imagery processed. Tick mark locations shall be computed for, and located on, the image format borders (which lie outside the actual image area) and identified with reference to pixel and line number of the corresponding image. Tick mark locations are to be computed with respect to the specified map projections and expressed in coordinate units peculiar to each projection.
- 3.4.3.2.13 Framing - The DMS shall have the capability of breaking up a continuous swath of input data into frames of predetermined size. Framing of Landsat-D and D' imagery will be based upon a World Reference System (WRS) where each frame center is identified by a unique latitude and longitude peculiar to the Landsat-D and D' mission orbital parameters. The contractor shall be responsible for defining and documenting the WRS, including providing a WRS nominal frame center listing, for both Landsat-D and D'.

The framing function shall provide for frame overlap of consecutive frames of not less than 2 percent or more than 5 percent, after the data has been geometrically corrected. Overlap marks shall be imbedded in the corrected image data at the beginning and end of the appropriate image scan lines.

- 3.4.3.2.14 Annotation - Image annotation data consistent with that provided for Landsat-3 shall be provided by the DMS. These data consist of alphanumeric information such as frame identification, instrument and mission parameters, tick mark locations and labels, and type of processing applied.
- 3.4.3.2.15 Temporal Registration - As a by-product of Geometric Correction using control points, all fully corrected image data produced by the DMS shall be temporally registered. Temporal registration is defined as the inherent registration achieved, in the digital domain, between any two corrected images when both are corrected to the same WRS reference. This shall be accomplished within the DMS through the use of a set of previously selected control points for each WRS frame. The set of control points may be either geodetic control points or relative (reference) control points.
- Whenever the set of control points used to model the geometric correction were selected from a Landsat-D or Landsat-D' image, that image shall be identified as the reference image by scene ID, in the corrected image. Otherwise no reference image is identified. ~~At~~ relative measure of registration accuracy (quality) shall be included with each image.
- The ability to perform temporal registration shall apply to MSS imagery from both D and D', and to TM imagery. Temporal registration shall be required between MSS and TM as a by-product of geometric corrections when Geodetic control points are available.
- 3.4.3.3 Product Generation Functions - The DMS shall have the capability of providing both partially processed and fully corrected imagery as output products.
- 3.4.3.3.1 Partially Processed Imagery - A partially processed image product is one in which the imagery (both TM and MSS) has been radiometrically corrected but not geometrically corrected. Partially processed imagery has appended to it, for each WRS frame, interpolation grids so that the imagery may subsequently be resampled into any of the specified map projections. Annotation data (tick mark locations, etc.) corresponding to specified map projections are also appended to each frame.

Partially processed images will be produced in a digital form on High Density Tape. The image data will be recorded on tape in a Band Interleaved by Line (BIL) format for TM data and in a Band Sequential (BSQ) format for MSS. The HDT'S so produced will be the archival medium for all TM and MSS image data processed by the DMS. Partially processed imagery can also be produced on CCT's for distribution to users/agencies or for sensor and process quality assessment and selectively, on 241 mm film for sensor and process quality assessment.

3.4.3.3.2

Fully Corrected Imagery - A fully corrected image product is one in which the imagery (both TM and MSS) has been both radiometrically corrected and geometrically corrected to one of the specified map projections. Annotation data corresponding to the map projection to which the image was corrected are appended to each frame.

Fully corrected imagery is produced on HDT (TM only) from partially processed imagery (the Archival HDT). Fully corrected TM image data will be recorded on HDT in a Band Sequential (BSQ) format. Fully corrected imagery for both MSS & TM can also be produced on CCT's and 241 mm film for distribution to users/agencies (TM only) and for sensor and process quality assessment (MSS and TM).

3.4.3.3.3

Digital Products - The following digital image products shall be produced by the DMS:

3.4.3.3.3.1

Archival High Density Tape - Partially processed imagery recorded on HDT in a BIL format for TM or in a BSQ format for MSS with the necessary geometric correction data (interpolation grids) and annotation data appended. All MSS and TM instrument data processed by the DMS will be provided in this medium. There will be separate archival HDT's for TM and MSS. Separate archival HDT's are not required for Landsat-D MSS and Landsat-D' MSS. The format and content of the partially processed MSS HDT product must conform to the specifications/description in the documents referred to in Paragraph 2.1.7.4 and 2.1.7.5.

3.4.3.3.3.2 Output High Density Tape - Fully corrected TM image data recorded on HDT in a BSQ format with the necessary annotation data appended. Fully corrected MSS imagery is required only for DMS performance evaluation and process verification and will be produced on CCT only.

3.4.3.3.3.3 Computer Compatible Tape - User CCT's, of TM data only, will be provided on both 9 track, 1600 bpi digital tape and 9 track, 6250 bpi digital tape. Capability shall exist to provide image data on CCT in the following formats with any required ancillary or annotation data appended:

- o Partially processed - BIL
- o Partially processed - BSQ
- o Fully corrected - BIL
- o Fully corrected - BSQ

The capability shall exist to provide CCT's of TM data, in any of the above formats, containing selected segments (or sub-images) of a frame. To provide the segmented digital product, the frame shall be divided into 4 fixed sub-images (quadrants), any combination of which can be specified by a user. Image quadrants selected from the same frame shall be digitally mosaicable (i.e. no overlap between quadrants). CCT's of MSS data in a partially processed - BSQ or a fully corrected - BSQ full scene format will be provided on both 1600 bpi and 6250 bpi digital tape for sensor and process quality assessment and system performance evaluation.

Additional output CCT's shall include inventory tapes for all High Density tape and 241 mm film products.

3.4.3.3.4 Film Products - The DMS shall have the capability of exposing 241 mm (9 1/2 in.) latent film masters. Input to the film recorder shall be either partially processed or fully corrected TM or MSS imagery.

Performance requirements for the film recorder are specified in the document referred to in Paragraph 2.1.7.3.

All film processing services will be provided external to the DMS. However, the DMS must provide work orders and tracking of requested photographic services. Latent film produced by the DMS shall be processable within existing GSFC photo facilities.

3.4.3.3.5

Tape Duplication - The duplication function shall permit copying of data from one tape to another. It shall be possible to perform:

- o HDT to HDT copying at the maximum high data rate recorder record/reproduce rate
- o HDT to CCT reformatting/copying at a rate commensurate with CCT unit
- o CCT to CCT copying

3.4.3.3.6

Tape Storage Functions - All long-term (greater than 6 months) tape storage facilities will be provided external to the DMS. The mission contractor shall provide as a part of the DMS, a short-term (less than 6 months) or "working" tape storage facility. Dibold or equivalent storage systems shall be provided to support all short-term and working tape storage requirements within the tape storage facility. The appropriate services such as storage, retrieval, accounting, and tracking of all system tapes either in "working" or long-term storage shall be provided as part of the DMS.

In addition, tape support equipments such as rewinders, cleaners and degaussers for high density tapes shall be included. Redundant equipments shall be provided to ensure production requirements.

3.4.3.4

Data Base Management Functions - The data base management function shall provide all of the required data management, production control, and system process control functions for the processing of MSS and TM data through the DMS. All data base management control functions for MSS are limited to HDT-AM, archival products, and do not apply to performance evaluation and quality assurance products. The major functions performed by this element are specified in the following paragraphs.

All data base management functions must support dual spacecraft operation where applicable and must be trackable both jointly and separately.

MSS data from both Landsat-D and D' will be mixed on HDT-R's. The data base management functions must accomodate this mix, in both its processing work order generation role, and it's accounting and traceability role.

The TM and MSS data will not be mixed on HDT-R's, nor is a common data base desired. The TM data base must include the same information and support the same processes as required for MSS, but shall be totally separated from the MSS data base.

3.4.3.4.1

Archival Product Generation - This includes all mission-related functions necessary to process all acquired imagery to an archival medium, such as:

- o Scheduling processing of raw data into partially processed archival data
- o Generating ancillary and annotation data
- o Creating data base of available imagery
- o Scheduling and tracking rework and regeneration of unacceptable data on an interval and scene basis

3.4.3.4.2

Support Services - This includes functions required so that agencies can request and obtain data from the DMS, such as:

- o Creating data base of agency standing order requirements
- o Providing interactive query capability to data base of available imagery collected over the life of the mission
- o Processing standing order requests
- o Processing retrospective requests against archive
- o Monitoring shipment of data to users/agencies

3.4.3.4.3

Agency Product Generation - This includes functions required to control the generation of products by the DMS, such as:

- o Scheduling processing of archival data into agency (or user) products
- o Handling redundant (duplicate) input data from dual coverage by 2 GSTDN Stations
- o Generating work orders for nonstandard or "special" requests
- o Generating work orders for photo lab processing and monitoring completion
- o Generating shipping/packing lists and monitoring completion
- o Scheduling rework of unacceptable products
- o Rebuilding faulty input ancillary files
- o Generating of output inventory tapes for user/agency digital or film products

3.4.3.4.4

Management Reporting - This includes functions which aid in tracking and controlling the flow of data through DMS such as:

- o Providing catalogs of available imagery
- o Providing work order status and tracking
- o Providing throughput, processing timelines and volume statistics for the DMS for each product
- o Providing inventory of agency (and users) standing orders
- o Providing accounting reports for agency and user product flows
- o Providing accounting of every production run with the attendant data quality
- o Providing Product Defect and Equipment Service Reports

3.4.3.4.5

Mission Management - This includes functions necessary for long range and day-to-day flight segment operations planning, scheduling, and mission performance evaluation, such as:

- o Maintaining a common data base to be shared between the OCC and DMS
- o Compiling image coverage requirements
- o Preparing daily and summary mission management reports
- o Providing remote terminal query of status
- o Communicating with Landsat-D OCC, via a computer to computer link, all necessary user request and management data
- o Providing for interactive access to the mission management data base from the following locations:
 - o Mission Management location - for hands on access to the data base computer
 - o Operations Control Center - for scheduling visibility
 - o Image Generation Function - for scheduling visibility and label generation
 - o DMS Tape Accounting Subsystem - for tape labeling, label reading and tracking
 - o Bldg 23 - for photolab and shipping production control
 - o Bldg 28 Staging - for shipping production control and accounting

3.4.3.4.6

Miscellaneous Functions - Additional functions of the Data Base Management element should include:

- o Common I/O service, file maintenance, file/data base protection and restoration, and application utility routines for the DMS
- o Providing the means for system, subsystem, and device calibration and test procedures
- o Providing the means to back-out erroneous data items that are used in archive generation and reschedule archive processing
- o Providing capacity and means to support software development and special engineering tasks
- o Providing an automated product defect and failure analysis tracking system
- o The implementation of quality assurance procedures including formatted dumps of image product CCT's, inventory CCT's, and CCT's that transfer ancillary data into the DMS
- o Generating performance and deviation reports on both the system and subsystem levels
- o Providing a GAO compatible inventory control system to monitor ground system spare parts and expendables. This system should be equivalent in capability to the Logistics Inventory Control System (LICS) available in the GSFC Image Processing Facility
- o Data base verification techniques to operationally establish the integrity of the major archive files, and of the data base management techniques

3.4.3.5

DMS Operation - This section describes requirements pertaining to DMS operation and production aspects. These requirements reflect on DMS design features which will permit execution or performance of data handling, data processing, and product generation functions not only under normal conditions, but also under abnormal conditions with regard to data quality, spacecraft and sensor performance, DMS device malfunctions, and operator intervention.

3.4.3.5.1

Data Handling - The DMS design must tolerate bad to good quality or missing image data without interrupting processing. The system shall have the capability to maintain synchronization with input data under conditions such as bit errors, scan line dropout or sync loss, time code errors, etc. The occurrence of error conditions shall not cause erroneous data selection or endless searching. Error recovery from normal errors (those which are known to occur randomly and frequently) shall be automatic. Operator assisted error recovery shall be necessary only in the case of unusual errors (those occurring infrequently or caused by device malfunction). Any discrepancies and error recovery procedures taken shall be noted on the printed report which is generated with the completion of each run. Image data of questionable or known poor/bad quality shall be appropriately flagged as such. The mission contractor will define various error conditions, the criteria for their evaluation/identification, and the action taken by the DMS whenever those errors occur.

The ability to automatically schedule rework of archival products shall be available in both interval and scene subsets. A parameter shall be available to software to determine whether to reschedule the entire interval, or selected scenes.

3.4.3.5.2

Data Processing - The DMS design shall provide the configuration and operational modes necessary to accept raw Landsat-D and D' sensor data and generate the output products previously specified.

The DMS design shall permit direct processing operations (i.e., normal production processing of image data) and preparatory operations (i.e., geodetic control point location, data base updates, etc.) to be executed in parallel. The execution of preparatory operations or functions, which may require operator interaction, shall not interfere with normal data flow and processing.

The DMS shall be designed to operate in two modes: automatic and manual. In the automatic mode, operator intervention is not required following system setup and initialization except in the event of nonrecoverable errors or other unusual occurrences. In the manual mode, the operator can override any programmed function/operation and set up the system device and processing configuration at his discretion.

There shall be a finite number of processing scenarios. The operator will select the one corresponding to the particular process to be performed. After the initial selection, all further setup and initialization commands or queries will be presented visually (on a CRT display) to the operator and the operator will be required to respond. Parameter choices available to the operator shall be displayed for his selection. The system shall verify operator inputs as much as is practical (i.e., at least for proper format or structure). The design of processing scenarios shall attempt to minimize the need for operator decision making.

Any action required by the operator shall appear as a prompting message on the CRT. The system must verify that the required action was taken before proceeding.

The system shall automatically verify DMS readiness to proceed with a specified production run. This would include the verification of proper device configuration, tapes mounted and ready, and processing instructions.

The DMS shall provide a complete accounting of every production run. This hardcopy report shall identify:

- o Initialization and setup procedure
- o Data processed
- o Mode
- o Processing anomalies
- o Data quality
- o Processing quality (i.e., an estimation of geometric accuracy)

The DMS design shall include specially designed tests, with appropriate test data, that can be used to verify DMS performance and ensure system readiness to begin daily production activities. Failure to meet specified performance requirements shall result in the identification of the faulty device.

3.4.4 Performance Requirements - The DMS shall be capable of meeting or exceeding the requirements specified in the paragraphs below. Performance is specified in terms of data rates, data volume, data throughput, and processing accuracy.

3.4.4.1 Data Handling Performance

3.4.4.1.1 Input Data Rate - The DMS shall capture MSS and TM Flight Segment sensor data at the rates specified in section 3.4.3.1.1.1. Capture in this context includes recording the input data as well as the on-line performance of all attendant processing functions necessary to monitor Flight Segment performance and verify data integrity.

3.4.4.1.2 GCP Library Buildup - The DMS shall be capable of building a GCP Library at a rate of not less than 100 control points (geodetic or relative) for each sensor per day. Utilization of the control point station shall not impact the DMS image processing throughput.

3.4.4.1.3

Input Data Volume - Total image data input to the DMS per day for the Landsat-D and D' mission time frames are as follows:

Landsat-D	200 MSS scenes 12 TM scenes per day as required (raw data capture only)
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Landsat-D and D'	200 MSS scenes (A mixture of MSS scenes for both Landsat-D and Landsat-D')
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Begin July 1983	12 TM scenes per day as required
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Begin Jan. 1985	100 TM scenes per day
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3.4.4.1.4

Output Data Volume - Total image data output by the DMS per 16-hour day, except as noted, for the Landsat-D and D' mission time frames will be as follows:

- o Recorded on High Density Tape

Landsat-D

200 MSS scenes (archival, partially processed) Archival set of HDT's plus one duplicate set

Landsat-D and D'

200 MSS scenes (archival, partially processed) Archival set of HDT's plus one duplicate set

Beginning July 1983

12 TM scenes (archival, partially processed) Archival set of HDT's plus one duplicate set per 8-hour day.

12 TM scenes (output, fully corrected) Original set of HDT's plus one duplicate set per 8-hour day.

Beginning January 1985

100 TM scenes (archival, partially, processed) archival set of HDT's plus one duplicate set.

50 TM scenes (output, fully corrected) original set of HDT's plus one duplicate set

- o 241 mm (9 1/2 in.) First Generation Film Masters

Landsat-D

Up to two percent of the MSS acquisition as required to perform Quality Assessment and Performance Evaluation

Landsat-D & D'

Up to two percent of the total MSS acquisition as required to perform Quality Assessment and Performance Evaluation

Beginning July 1983

12 TM scenes per day (per 8 hour day)

Beginning January 1985

50 TM scenes

- o Computer Compatible Tapes (CCT's)
Landsat-D

2 MSS partially and/or fully processed scenes

HDT inventory tapes as required

Landsat-D & D'

2 MSS partially and/or fully processed scenes

HDT inventory tapes as required

Beginning July 1983

2 TM partially and/or fully processed
scenes per 8 hour day

HDT and Film inventory tapes as required

Beginning January 1985

10 TM partially and/or fully processed
scenes

HDT and film inventory tapes as required

- o 70 mm First Generation Film Masters
Landsat-D

MSS - 1 of 4 bands, selectable, of all
partially processed scenes

Landsat-D & D'

MSS - 1 of 4 bands, selectable, for all
partially processed scenes

TM - 2 of 7 bands, selectable for all
partially processed scenes

- 3.4.4.1.5 Data Turnaround - The maximum throughput or
turnaround time through the DMS required to
generate any DMS product from raw input data
shall not exceed 48 hours.

- 3.4.4.1.6 Data Recording Efficiency - The capability to
provide a recording efficiency on both TM and
MSS archival HDTs of at least 80 percent,
independent of the raw tape packing
efficiency shall be provided. This means that
bits of image data recorded on an archival HDT
shall be at least 80 percent of the total or
maximum HDT capacity in bits. Single scene
data will not be split between HDTs.

- 3.4.4.2 Data Processing Performance - Data processing performance is specified in terms of processing accuracies resulting from the processing methods, algorithms, and equipment which comprise the total DMS.
- 3.4.4.2.1 Radiometric Correction - The DMS shall radiometrically correct both TM and MSS instrument data to a relative accuracy of +1 quantum level over the entire dynamic range. This accuracy shall apply to detectors in the same spectral band within a group (mirror sweep). Achieving this radiometric accuracy will require the computation of correction values based upon both detector calibration data and image contents.
- 3.4.4.2.2 Geometric Correction - The DMS shall geometrically correct both TM and MSS instrument data to an accuracy within 0.5 instrument pixel (resolution element), 90 percent of the time, with reference to a standard map. Achieving this absolute geodetic accuracy will require the use of Geodetic Control Points (whose positions are assumed to be accurate). This performance accuracy will be verified over areas where there will be no errors due to Earth Topographical Variations. Errors due to spacecraft momentum effects (jitter errors) will be allowed to be additive to the .5 pixel TM accuracy specification with the initial TM processing system on July 1983. Jitter compensation necessary to meet the .5 pixel accuracy requirement will be implemented during the TM R&D phase.
- 3.4.4.2.3 Resampling - Resampling shall not introduce radiometric degradation of more than +1 quantum level. Cubic convolution resampling shall not introduce greater than 0.3 pixel distortion or shift in spatial features such as roads, rivers, faults, etc.
- 3.4.4.2.4 Tick Marks - Tick mark locations shall be computed at intervals of 50,000 meters for the specified coordinate systems. Computational accuracy shall be commensurate with that of geometric correction.

3.4.4.2.5

Temporal Registration - The registration of an input image to its corresponding reference image shall be within 0.3 pixel 90 percent of the time. This requirement assumes adequate instrument performance will be achieved and does not include errors that may be attributed to uncompensated spacecraft momentum effects. Corner points of the registered image (pixel and line number) must be identified with the corresponding point of the reference image so that there is a one-to-one correspondence of pixels within the registered area.

When registering MSS with higher resolution TM (or IR with higher resolution visible), registration accuracy will be commensurate with the lower resolution instrument.

The Mission Contractor shall define the temporal registration technique, a complete error budget, and a method to verify conformance with the specified requirements.

3.5 LANDSAT-D ASSESSMENT SYSTEM REQUIREMENTS

3.5.1

Introduction - The Landsat-D Assessment System (LAS) shall be the equipment and associated system software required to meet the research objectives of the Landsat-D mission and to demonstrate the application of the TM data in specific research projects. The LAS hardware shall be delivered by the mission contractor, with the exception of the scanner digitizer, which will be provided by NASA. All spares and supplies for testing will be delivered by the contractor as well as the systems software for the image analysis terminals (IAT) and the high density digital recorders (HDDR). All hardware is to be unit tested and the IAT and HDDR subsystems are to be integrated and tested on the main processor. The mission contractor will not be responsible for the systems software for the CCT subsystem and the film recorder subsystem nor for overall integration and test. The applications software required to meet these objectives will be developed by the government, principal investigators, and user agencies and is not a part of this specification but the system software (Section 3.5.5) is part of this specification. It is required, however, that this software operate on the LAS; therefore, a functional description of the research is included in Section 3.5.2 for the purposes of system design.

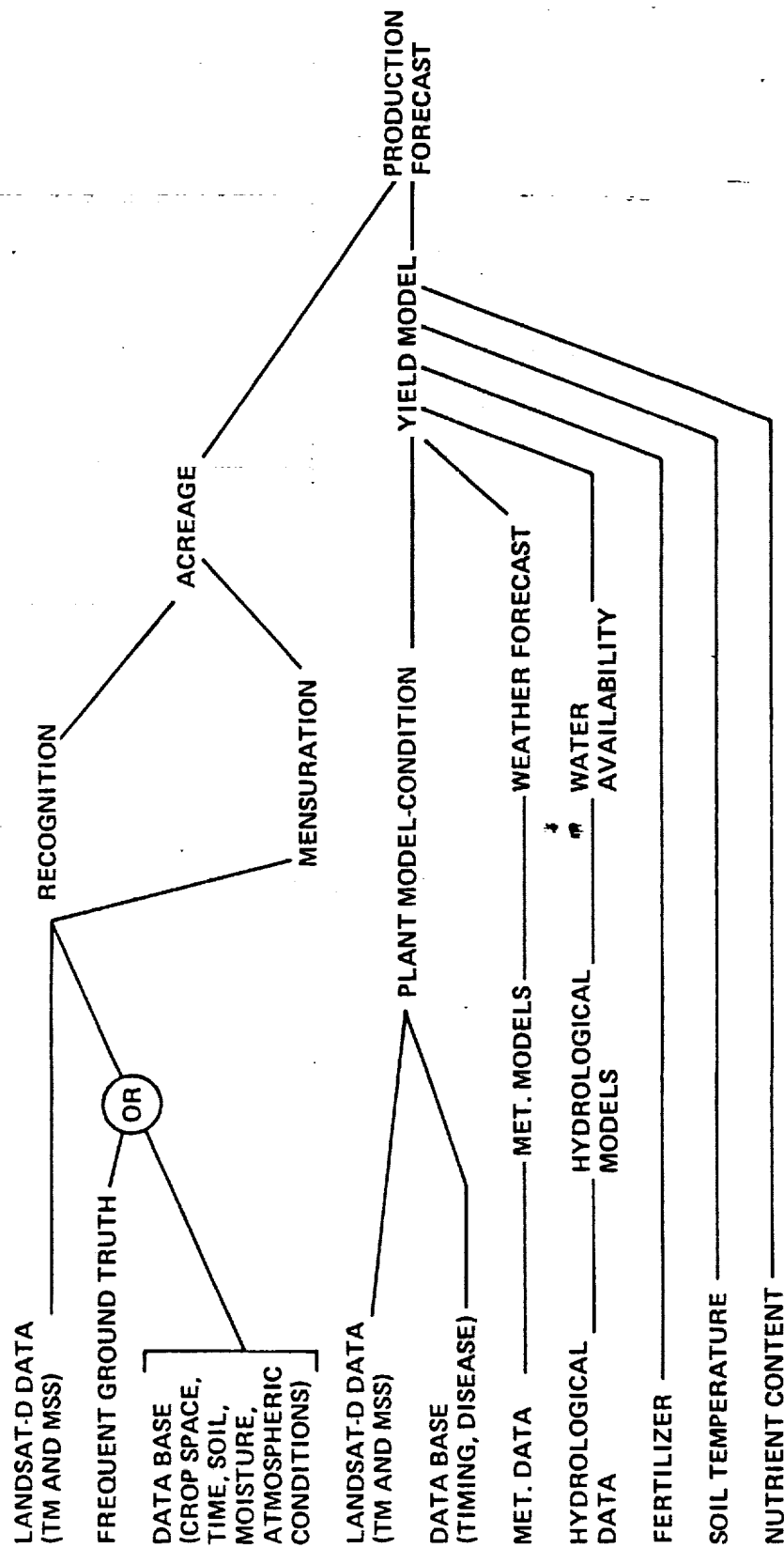
The primary emphasis in the use the LAS will be in the form of performing studies to serve to quantitatively exemplify the advantages of the TM versus the MSS and verifying and refining the data processing procedures used in the Image Generation Facility.

3.5.2

Functional Requirements - The Landsat-D Assessment System will provide the facilities necessary to do the user research required to develop and verify data processing algorithms that permit radiometric and geometric correction to be applied to TM and MSS data and to perform the research which provides quantitative examples of the advantages of the TM over the MSS for earth resources applications. In the first instance algorithms will be developed or existing algorithms improved so as to account for uncompensated momentum effects introduced by the TM and MSS scanning and operation the various spacecraft appendages; e.g., TDRSS antenna boom, solar array, as well as image stripping, variations in calibration during sensor lifetime, data drop-out during transmission, or other data quality problems or anomalies. In the second instance user studies will be performed which illustrate the advantages of the TM relative to the MSS in terms of spatial resolution, spectral band widths and new spectral bands, radiometric sensitivity and dynamic range, etc. These will be performed so as to illustrate these advantages for a wide range of disciplines including agriculture (e.g. small field mensuration, crop identification, vegetation stress monitoring), water resources and hydrological studies management, mineral and petroleum exploration or geological studies, land use mapping and monitoring, cartographic applications, coastal zone studies, and bathymetry in uncharted areas. The mission contractor shall be responsible for sizing and configuring the LAS to perform the functions specified in the following paragraphs.

a) Small Field Mensuration. The Thematic Mapper will provide the necessary spatial resolution to classify and measure small agricultural fields, such as the wheat fields found in China, India and many European countries.

b) Crop Yield. The Thematic Mapper data will provide a direct assessment of plant condition for improvement of the yield model for various crops.



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Figure 3.5.2-1. A Model of Crop Production Forecasting

- 3.5.2.1 Image Registration - The LAS shall be sized and configured to match TM and MSS images with ancillary image data sets using correlation techniques. Typically 30 to 40 control points will be required to generate the interpolation grids for geometric correction. The software to perform these functions is not part of this procurement.
- 3.5.2.2 Geometric Correction - The LAS shall be capable of performing geometric corrections on partially processed TM data using the interpolation grids produced by DMS. The resampling methods implemented shall include nearest neighbor, bilinear and cubic convolution. The software to perform these functions is not part of this procurement.
- 3.5.2.3 Multi-dimensional Classification - The LAS shall be sized and configured to perform feature selection, supervised classification and clustering on images up to a size of 50 x 50 km and 14 channels (multi-temporal classification). The software for these functions is not part of this procurement.
- 3.5.2.4 Image Enhancement - The LAS shall be sized and configured to perform multi-image enhancement. Enhancement methods will include contrast enhancement, ratioing and spectral transformations to principal components for false color display. The enhancement functions shall be applied to a full scene. The software for these functions is not part of this procurement.

3.5.2.5

Yield Estimation - The LAS shall be sized and configured to perform crop yield estimation using regression and simulation models. Typical regression models will involve up to 20 independent variables requiring up to 500 K bytes of main memory. These models will provide estimates for areas up to 100 x 100 km. A typical simulation model involving difference equations with up to 30 state variables will require up to 500 K bytes of main memory and will estimate yield for individual fields. The yield models will use Landsat-D, TM, meteorological and ancillary data as shown in Figure 3.5.2-1 and will be updated on a daily basis. Classification will be performed to determine plant condition and field mensuration. The software for these functions is not part of this procurement.

3.5.2.6

Land Use Mapping and Land Use Changes - The LAS shall be sized and configured to perform land use mapping with up to 30 classes utilizing TM data. Typical areas of interest will have a size of 50 x 50 km with a total of 20 case studies processed per year. Changes in land use patterns shall be detected and their area extent quantified. The software for these functions is not part of this procurement.

3.5.2.7

Geologic Mapping - The LAS shall be sized and configured to perform geologic mapping of areas up to a size of 100 x 100 km. Methods will include ratioing, transformation to principal components and contrast enhancement. The capability to detect linear features in TM images will be analyzed. The software for these functions is not part of this procurement.

3.5.3

Operational Requirements

3.5.3.1

Input. Input data to the LAS will consist of:

- o fully corrected Landsat image data on HDT in a band sequential (BSQ) format.
- o partially processed Landsat image data on HDT in a band interleaved by line (BIL) format.
- o ancilliary data on CCTs at 1600/6250 bpi containing correlative information on e.g., soil moisture and parameters relating to weather and climate.
- o data transmitted over a communication line interconnecting the LAS with a data base residing on a remote computer.
- o film transparencies of maps, grids and other image data to be used in conjunction with a digital scanner and to be overlayed on the TM data.
- o correlative data including imagery on CCTs from sensors onboard other spacecraft.
- o correlative information on punched cards.

3.5.3.2

Output. Output data from the LAS will consist of:

- o extracted subscene information on HDTs.
- o processed TM data on CCTs in a format compatible with display on a high resolution image recorder.
- o intermediate or archival information extracted from the TM imagery, e.g., thematic maps, crop acreage, land use, etc. contained on HDTs and CCTs.
- o partially processed and/or fully processed TM data on CCTS.
- o statistical, tabular information displayed on line printer.
- o information relating to system use and accounting, management reports, data catalogs.
- o latent images.

3.5.3.3

Input/Output Equipment

- o High Density Tape (HDT) Recorders. These units must be fully compatible to those used to record Landsat-D MSS and TM image data for distribution to the EROS Data Center (EDC).
- o Magnetic Tape Units. Magnetic tape units shall be provided for input/output of CCTs in 1600/6250 bpi densities, using standard magnetic tape reels, and operating at speeds of at least 125 inches per second.
- o Input Scanner/Digitizer Unit. One input scanner/digitizer unit shall be provided by NASA/GSFC to be connected to one image analysis terminal (IAT). The contractor shall verify that the scanner/digitizer input signal is transferred successfully to the IAT and that a proper digital image of the scanner input is stored in the IAT refresh memory.

The IAT shall provide the following RS-170 standard signals for operation of the input scanner/digitizer (ISD):

- Composite blanking, 2.0 - 6.0 V pp (75 ohm input)
- H-Drive, 2.0 - 6.0 V pp (75 ohm input)
- V-Drive, 2.0 - 6.0 V pp (75 ohm input)
- Composite sync, 2.0 - 4.0 V pp (bridging input)
- Composite blanking, 2.0 - 4.0 V pp (bridging input)

The video output of the ISD shall be 1.3 volts nominal peak-to-peak, clamped at black level, and will require 75 ohm terminations.

- o Image Recorder. An off-line image recorder capability shall be provided to produce latent images for the subsequent generation of black-and-white or color prints and transparencies of annotated images. A photographic processing laboratory is not part of LAS.

The recorder shall provide the following capabilities:

- 256 exposure levels (8 bit code) for each input (red, blue, green)
- exposure beam shall be modulated to produce exposures either linearly or logarithmically related to the exposure code
- output film product resolution shall conform to TM sensor resolution of 6176 pixels by 6176 lines and the MSS sensor resolution of 3240 pixels by 2340 lines
- o Card Reader. System card reader(s) shall be provided for input of punched card information. Unit(s) shall be operate at a speed of at least 200 cards per minute.
- o Line Printer. System printer(s) shall be provided with shade print/plot capabilities using a 200 dot per inch format, 132 characters per print line, at a speed of at least 1000 lines per minute. An impact printer shall be provided which outputs 132 characters per print line at a speed of 300 lines per minute.
- o (Deleted)

3.5.3.4

Main processor(s) shall have a word length of 32 bits. Direct byte and word addressing of main memory is required. At least 896K bytes of memory shall be provided with the system. The main processor(s) shall be capable of floating point operations in hardware. All Input/Output equipment, except the Digitizer Input Scanner Unit and film recorder subsystem, shall be directly interfaced to the main processor to allow rapid and efficient equipment fault location and diagnosis. Input/Output equipment shall be interfaced to the main processor in a configuration which will optimize parallel data transfers, and take advantage of the transfer bandwidth rate of the processor. Bulk data disc storage shall be provided and sized to store data from 2 full MSS and 2 full TM scenes on line. Three additional discs shall be provided to allow on line storage of interactive data sets created by the image analysis terminals users. An independent systems software disc shall also be provided. All disc drives shall have removable disc packs to facilitate rapid access of offline data, and shall be similar to provide redundancy in case of disc failure.

Array Processor. The array ~~BF~~ pipeline processor shall have a processor and main data memory word length of no less than 36 bits, in floating point format. The main data memory shall consist of no less than 256K words of 167 ns memory. The processor shall interface to the high speed bus of the host computer. The processor shall be capable of performing floating point arithmetic operations in hardware. The array processor shall have a writable program store of no less than 2000 instructions. The processor instruction set shall permit branching and subroutine call capabilities, shifting, and logical operations. The following host compatible software packages shall be provided for the array processor: an assembly language cross-assembler, FORTRAN callable math and scientific subroutines, a FORTRAN compiler, and all software necessary to write and debug assembly level programs.

3.5.3.5 Operational Modes. The LAS design shall permit interactive, batch and mixed processing modes. Simultaneous operation of two independent interactive activities using the image analysis terminals and of background tasks is required.

LAS system and application programs shall be stored on disk in executable form in the systems library. These programs will be loaded into main memory and executed under user control in the batch or interactive modes.

3.5.3.5.1 Interactive Mode. User-system communication functions shall be provided for interactive operation. Users shall be able to define processing scenarios by selecting functions and specifying parameters on the alphanumeric CRTs. The interactive specification of a sequence of processing functions and their execution as a background task shall be possible.

3.5.3.5.2 Batch Mode. System capabilities shall be provided for the user to specify a sequence of LAS functions and application programs with their required parameters for batch execution.

3.5.3.6 Display. Two types of terminals are required by the LAS: 1) alphanumeric, 2) Image analysis.

3.5.3.6.1 Alphanumeric. The LAS shall provide system capabilities for displaying various forms of numeric information, annotation, statistics, system messages, data base reports, data catalogs, processing status messages, data plots and contours, and the results of digital analysis and information extraction operations. These kinds of information shall be displayed on alphanumeric cathode ray tube keyboard/display units which support limited graphics.

These units shall have the following capabilities:

- o terminal operator communication with the system
- o a single hard copy unit shall be provided to generate quick-look hard copy output products in a page size format.

3.5.3.6.2 Paragraph deleted

3.5.3.6.3 Image Analysis. Three image analysis terminals for data interpretation, information extraction, and applications research shall be provided with the following capabilities.

- o Sufficient solid state refresh memory to store eight TV-sized (512 lines by 512 picture elements per line) digital images using 8-bits to represent each picture element.
- o A hardware cursor (rectangle and cross hair types) with single pixel accuracy which functions under user joystick control for cursor sizing and positioning.
- o A high resolution color TV monitor of at least 19-inch, diagonal measurement.
- o Individual display of the contents of each refresh memory channel on eight small sized black and white TV monitors.
- o Direct control of all terminal switches and hardware options by the main processor.
- o Direct read and write of all terminal switches, hardware registers and processing circuitry by the terminal processor.
- o Hardware lookup table operations for each image channel under control of the terminal processor.
- o Image registration by displaying two images and moving one image over the other under user control.
- o Direct memory load and readout under computer control so that enhanced images and picture elements with a specified boundary may be transferred between the refresh memory channels and the terminal processor.
- o X-Y image translation within the refresh memories.
- o Image scrolling and multiple split screen displays.

- o Rapid refresh memory loading (at least one 512 x 512 image per second).
- o Image fade control for superposition of two images for registration and correlation operations.
- o Addressing one refresh memory channel as eight individual bit planes.
- o Bit plane registration by shifting individual planes.
- o Direct image rewrite/re-record capabilities in each refresh memory channel.
- o An array of programmable function keys which cause an interrupt within the terminal processor when depressed.
- o Computer controlled time lapsed displays of image sequences.
- o A capability to outline and select irregularly shaped image areas in images displayed on the color TV monitor (e.g., using a light pen).
- o A series of hardware registers to rapidly generate grey level histograms of image areas for spectral signature acquisition.
- o Computer controlled hardware to combine thematic information using logical AND, OR, Exclusive OR and negation operations.
- o Image display terminal hardware and the image scanner shall conform to the 525 line, 30 frame per second (interlaced) U. S. commercial television standards. Proper image aspect ratio shall be maintained by insertion of blank image data around the 512 x 512 image to create a standard 525 line by 700 element per line image. Abnormal adjustment of monitor controls to maintain image aspect ratio is not acceptable.

3.5.3.7

Data File Management. The LAS shall provide the required data file management for LAS functions and application programs and the procedures necessary to create and maintain data files and the program library.

3.5.3.7.1 Data Management Functions. This set of functions shall provide the capabilities required by analysis, display and application programs to transfer data between main memory and peripheral devices.

3.5.3.7.2 Data File Management Functions. This set of functions shall provide the following capabilities:

- o Creating data files and associated catalogues
- o Accessing, retrieving and updating of data in the data files
- o Querying data file catalogues, generating, displaying and printing reports of the contents of data files
- o Unloading and restoring on-line data files

The data files associated with LAS will include off-line archival HDT and CCT data files containing Landsat-D and correlative data, on-line disk data files and remote data files separate from the LAS. The interface to remote data files will be via communication lines and magnetic tape.

3.5.3.7.3 Program Library. Functions shall be provided to insert program modules in executable form into the program library for later execution.

3.5.4. LAS Configuration. The LAS shall be configured so that the system:

- o Ingests the input data sources listed in Section 3.5.3.1
- o Has the capability to effectively perform required processing functions listed in Section 3.5.2
- o Provides the operational modes described in Section 3.5.3.5
- o Performs the display functions described in Section 3.5.3.6
- o Performs the data management/data base management functions listed in Section 3.5.3.7
- o Furnishes the output products listed in Section 3.5.3.2

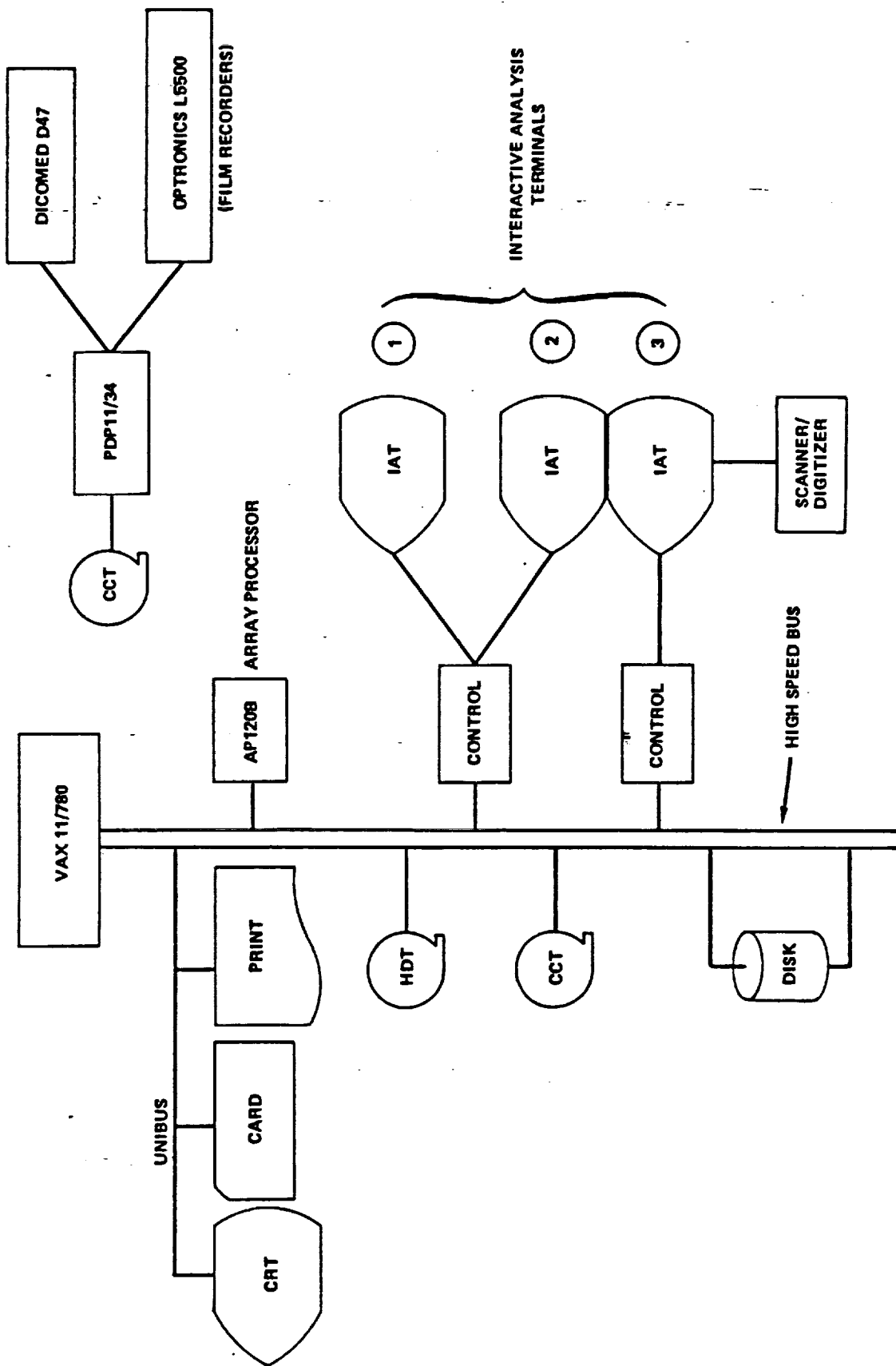


Figure 3.5.4-1. LAS Minimal System Configuration

A minimal configuration for the LAS is shown in Figure 3.5.4-1. The main processor has a low speed and high speed data bus. A programmable array processor is connected to the main processor to rapidly perform image processing functions as specified in Section 3.5.2. Peripherals including the image analysis terminals are interfaced to the main processor's high speed bus to accept or transmit large volumes of data at high rates. Input data is ingested into the system from the tape drives, and placed on the bulk data disks for on-line storage. Sufficient storage space is allowed to contain 2 TM and 2 MSS scenes, plus working space for the array processor. System software will reside on a disk used exclusively for this purpose and storage of program libraries.

The image analysis terminal user discs will store extracted sub-scene image information and other processed image data being used interactively. There are 3 individual discs, one for each terminal, to provide backup for the system disc and allow contention free access of the users to the data on the discs. The image analysis terminals are connected to the bulk data base, user data base, main processor, and the array processor to allow rapid data access.

The LAS shall be so designed as to have additional input/output channel capacity to facilitate the interfacing of other GFE ADP equipment not specifically called for in this specification. Examples of this equipment are the GSFC Space Science and Applications IBM 360/91 and the Atmospheric and Oceanographic Information Processing System (AOIPS), the main processor of which is a DEC PDP 11/70. The LAS shall be so designed as to be independent and separate from the DMS.

3.5.5

System Software - System software required for delivery with the LAS includes a basic operating system and the LAS control system. The control system shall permit execution of all LAS functions in the required operational modes. The control system shall also provide the environment for the installation and execution of application programs which are not part of this procurement.

The operating system to be delivered shall include:

- o Fortran IV compiler
- o macro assembler
- o file system
- o text editor
- o mathematical and statistical subroutine package
- o computer use accounting system
- o system routines and device handlers for all devices delivered with the LAS

The control system software to be delivered shall include:

- o software to read TM and MSS data from HDT in both BIL and BSQ formats
- o software to read data from the digitizer
- o software to write processed data to HDT for archiving
- o Deleted
- o software to perform all required display functions including operation of the image display terminal and the image analysis terminals
- o software to operate the shared disk and communication links in the event more than one main processor is proposed
- o software to perform all the data management and data base management functions
- o Deleted

3.5.6

Performance Requirements - The LAS shall be capable of processing an average TM data volume of 2.5×10^8 bytes per day. In addition, to the TM data, a daily volume of 1.0×10^8 bytes of MSS, meteorological and other correlative data shall be processed by the LAS. It is planned that the LAS will be operated 16 hours per day, 5 days per week. The expected maximum peak load is 5×10^8 bytes per day. This data volume shall be processed through the functions listed in Section 3.5.2 (geometric correction, classification, modelling, etc.). The LAS must be designed to permit simultaneous execution of any two processing functions as specified in Section 3.5.2. The LAS shall be designed to meet the following performance criteria:

- o System response to terminal user input shall not exceed 2 sec.
- o The transfer rate for loading a refresh memory of the image display terminal shall be at least 1 TV-sized image per second.
- o The rate of change for alternate display of two images on one image display terminal shall be user controllable from 4 to 60 refresh cycles.

3.5.7

Site and Support Facilities

3.5.7.1

Floor Space - The total amount of contiguous floor space available for the LAS will be 5000 sq. ft.. Of this, 2000 sq. ft. will be available for the LAS computer area including tape storage and a programming room; 500 sq. ft. will be available for each image analysis terminal area.

3.5.7.2

Power - The LAS shall use a primary power source at 208 VAC, 3 phase, and a secondary source at 118 VAC single phase. Each power entry into the LAS shall be electrically protected. The LAS power requirements shall be identified.

3.5.7.3 Air Conditioning - All equipment must operate in an environment wherein the following conditions will be maintained:

	<u>Operating</u>	<u>Nonoperating</u>
Relative Humidity	40% - 60%	30% - 85%
Temperature	20°C - 25°C	10°C - 35°C
Gradient	1°C/hour	2°C/hour
	2% RH/hour	4% RH/hour

The LAS air conditioning requirements shall be identified.

3.5.7.4 Grounding and Power Distribution - All DC power and related ground lines shall originate from a single bus source in each chassis and from the main power distribution point. AC, DC, and video grounds shall be isolated to eliminate ground loops. Star connected power and ground distribution is recommended.

4.0

FLIGHT ASSURANCE REQUIREMENTS

4.1

INTRODUCTION

This section establishes the Flight Assurance Requirements to be implemented for the Landsat-D System. The Flight Assurance Program shall include appropriate provisions for: (a) the Flight Segment, consisting of the Mission Unique subsystems, the Government-Furnished MMS and instruments, (b) the Flight Segment GSE, (c) the Ground Segment, and (d) Systems Safety. The program shall be developed based on NASA Reliability and Quality Assurance Publications (NHB 5300.4(1A)) and NHB 5300.4(1B)) as further defined in the requirements of this section. Those paragraphs of the NASA publications not specifically referenced in this section are considered to be applicable as general guidelines. Paragraph 1A302 of NHB 5300.4(1A) on reliability prediction is deleted.

4.1.1

General

4.1.1.1

Government Monitoring - The contractor's operation will be monitored by GSFC and its designated representatives, under the provisions of Paragraphs 1A103 OF NHB 5300.4(1A) and 1B102 of NHB 5300.4(1B), to confirm compliance with Flight Assurance Requirements. The GIA participation will be primarily directed to selected inspections of manufacturing and assembly operations, auditing of product assurance documentation, and witnessing of integration and test operations.

4.1.1.2

Reliability Evaluation Contractor - An independent reliability evaluation contractor may be utilized in support of the Landsat-D Project.

4.1.1.3

Government Data - GSFC will furnish the contractor with ALERTS and other parts and materials data related to reliability, quality assurance, and safety. GSFC reserves the option to request the contractor to formally respond to the impact of any ALERT transmitted.

4.1.2

Plans

4.1.2.1

General - The contractor shall prepare detailed plans which describe the implementation of the requirements of this specification. The plans shall make maximum use of existing contractor systems, practices and procedures and incorporate only such changes and additional procedures as necessary to meet the requirements of this specification. The plans shall indicate any differences in dealing with new designs, modified designs, proven designs to be fabricated, off-the-shelf hardware used as is, and existing hardware to be modified or refurbished.

The plans must be sufficiently detailed, specific, factual, and concise to:

- o Permit GSFC to evaluate and assess the contractor's proposed effort for meeting the requirements of this specification
- o Commit the contractor to specific courses of action, method of execution, level of performance, and level of effort
- o Serve as the master planning and control document, used by both the contractor and GSFC to manage the program(s) during the period of contract performance. As a supplement to the plans, the contractor shall submit with his proposal one copy of procedures and specifications, which further define methods for implementation of the plans

Plans shall provide a clear and concise description of each task or activity to be accomplished. Each task shall be further identified in terms of:

- o Methods used in accomplishing the task
- o Organization(s) involved in the execution of each task
- o Standard procedures/instructions describing how each task is performed. These may be included by reference to title and control number

- o Schedules showing the start and completion of each task keyed to the project milestone the task supports
- o Participation of subcontractors/suppliers in each task

In addition to the text or work descriptions, the plans should also include the following:

- o Organization charts
- o Flow charts
- o Integrated matrix of each requirement vs. the applicable plan paragraph vs. the (standard) implementing procedure
- o Control of newly released procedures and changes to existing procedures including contractor and GSFC review and approval. Procedures referenced within the plans, which define Government involvement, shall be reviewed and approved by GSFC.
- o Table of Deliverable Documentation

- 4.1.2.2 Required Plans - The contractor shall submit the following plans.
- 4.1.2.2.1 Reliability Assurance Plan - Flight Segment
 - 4.1.2.2.2 Product Assurance Plan - Flight Segment
 - 4.1.2.2.3 Product Assurance Plan - Flight Segment Ground Support Equipment
 - 4.1.2.2.4 Product Assurance Plan - Ground Segment
 - 4.1.2.2.5 System Safety Plan
- 4.1.2.3 Plan Review and Approval - The GSFC will review, negotiate, approve, and accept all plans prior to contract signing. The plans shall be part of the contract. Subsequent changes to these plans shall be handled as configuration change requests and must be submitted in writing to, and approved by, the GSFC contracting officer prior to implementation. The contractor shall control referenced documents to assure that changes do not violate the intent of the plan.

4.1.3

Flight Assurance Progress Reporting - The contractor shall report on significant Flight Assurance activities as a part of the monthly project status review report. The reporting shall be brief, concise, and to the point, describing significant activities occurring during the previous reporting period as well as activities planned for the succeeding period. The report shall highlight problem areas, solutions, overall status, and other significant data. Actual manpower expenditures shall be included in the NASA Form 533's per the Work Breakdown Structure (WBS).

4.1.4

Deliverable Documentation - Deliverable documentation items are as specified in Section 6 and Section 4.7. Section 4.7 specifically lists Flight Assurance deliverable documentation. These lists do not include documentation developed and retained by the contractor to provide internal control and objective evidence of the performance of Flight Assurance tasks. GSFC reserves the option of reviewing this documentation at the contractor's facility.

4.2

RELIABILITY REQUIREMENTS - FLIGHT SEGMENT

4.2.1

Implementation - The contractor shall implement a basic reliability engineering program to accomplish, participate in, or review the following:

- o Preparation of design specifications for each item of hardware at the system, subsystem, and component level.
- o Failure mode effects analyses to determine possible modes of failure and their effects on mission objectives.

The exceptions to this requirement are the failure mode effects analyses covering the Instrument Module/Multimission Modular Spacecraft interfaces, the Angular Displacement Sensor Assembly, and the Earth Sensor Assembly Module/Multimission Modular Spacecraft interface which will be a GSFC responsibility.

- o Design considerations for maintainability of the system and elimination of human-induced failures from the basic design emphasizing areas related to hardware and software involved in ground operations, mission operations, retrieval and ground refurbishment.
- o Design Review programs established and conducted by the contractor providing comprehensive critical audits of all pertinent aspects of the design of hardware and software. These reviews are required at the system, subsystem, and component level.
- o Implementation of a "problem/failure reporting system," to control all aspects of nonconformances of a functional nature throughout the contract effort.
- o A formalized program to maintain a continuous effort to standardize and control design practices and fabrication processes.
- o A High Reliability program for parts, devices, materials, and processes to be used in the flight hardware
- o Implementation of a verification test program, covering environmental testing and analysis at the component, subsystem, and system level, to assure that the flight hardware will meet mission requirements, and the preparation of related test plans and environmental test specifications.

4.2.2

Review Program - The contractor shall implement a review program covering both internal reviews and the support of GSFC conducted reviews. The program shall include a formal closed loop system to ensure close-out of action items and to control recommended changes resulting from both contractor and GSFC reviews.

- 4.2.2.1 Contractor Reviews - The contractor shall implement a formal internal design review program using personnel other than those responsible for the design to review and assess the design at key project milestones. A record of all review activities and actions shall be maintained. The contractor shall notify GSFC of reviews at least five working days prior to the review. GSFC reserves the right to attend contractor reviews.
- 4.2.2.2 GSFC Project Reviews - The contractor shall conduct, jointly with the GSFC Project office, conceptual (new designs) and detailed (new and existing design) design reviews at the subsystem and the component level. Detailed agendas and the time of each design review shall be established by the contractor and coordinated with GSFC. Design review data packages shall be required 10 days before each review. In addition to the normal circuit/functional review, packaging design, manufacturing techniques and processes will be stressed to ensure that packages can be repaired without compromising reliability or quality.
- 4.2.2.3 GSFC System Reviews - The contractor shall present a series of Flight Segment level system reviews to a GSFC centerwide team of specialists, as identified in the following paragraphs:
- 4.2.2.3.1 Conceptual Design Review (CDR) - The CDR shall be keyed to the end of the design study phase. Preliminary design and design approaches will be emphasized.
- 4.2.2.3.2 Detailed Design Review (DDR) - The DDR shall emphasize implementation of the design approaches resulting from studies and development model testing. This review shall take place at the completion of the detailed design phase and shall cover the instrument module and mission unique systems in depth.
- 4.2.2.3.3 Pre-Environmental Review - The contractor shall implement this review before the acceptance/qualification testing of the Flight Segment is commenced. The review shall address the qualification status of the subsystems, integration and checkout results, and evaluate the flight acceptance test plans.

- 4.2.2.3.4 Flight Readiness - The contractor shall implement this review prior to shipment of the Flight Segment to the Western Test Range. The contractor shall address performance of the Flight Segment during acceptance testing.
- 4.2.2.3.5 Flight operations Review - The contractor shall key this review to a flight operations plan and evaluate the plan for orbital operations, data processing operations, and the interfaces within the Landsat-D system.
- 4.2.3 Reliability Analyses - Reliability analyses to be performed by the contractor shall include a Failure Mode and Effects Analysis, a Worst Case Circuit Tolerance Analysis, and a Parts Devices and Materials Applications Review (including electronic stress analysis). These analyses shall be completed for each component prior to the detailed design review with the GSFC project. Copies of the component analyses, extended to include system considerations, shall be submitted to GSFC at least one month prior to the GSFC system Detailed Design Review
- 4.2.3.1 FMEA - The contractor shall perform an FMEA for mission unique equipment and for degradation or failure at the MMS module interfaces. For mission unique equipments, the analysis shall start at the functional circuit level, and for MMS interfaces, the analysis shall start at the component (black box) level. The analysis shall continue through the system level. Particular attention shall be given to the identification of single point failures and the necessary corrective actions to be taken to decrease the susceptibility of the Flight Segment to their effects. FMEA's shall be updated to reflect design changes affecting the system performance or function. The contractor shall additionally use the results of the FMEA to assess the impact on the Flight Segment safety and hazards requirements.
- 4.2.3.2 Worst Case Circuit Tolerance Analysis - The contractor shall conduct a part level worst case circuit tolerance analysis to ensure maintenance of end-to-end system performance. Worst Case Circuit Tolerance Analysis shall be updated to reflect design changes affecting the system.

4.2.3.3

Parts Devices and Materials Applications Review - The contractor shall accomplish parts devices and materials application review program to meet the requirements of Paragraph 1A308-7 of NHB 5300.4(1A), as an input to the first detailed design review conducted for each component. This shall include electronic/electrical stress analysis for power sensitive and critical electrical, electronic, and electromechanical parts. A materials, stress, and functional analysis review shall be performed for mechanical devices. Appropriate attention shall be given to the radiation stress environment of any parts which are considered radiation sensitive in the anticipated Landsat-D mission environment. (See Paragraph 2.2.1.3). The application reviews shall be updated to reflect design changes affecting the system.

4.2.4

Parts, Materials, and Processes - The contractor shall use qualified parts and materials with emphasis on standardization to limit the number of different types used. The contractor shall control processes used.

Note: Electronic parts used in the Angular Displacement Sensor Assembly (ADSA) will be a GSFC responsibility. However, GSFC will require that certain of these parts be procured by the contractor in accordance with a GSFC submitted parts list. These parts will be subject to incoming inspection and testing at the contractors. However, any required screening tests, and destructive physical analysis on ADSA parts (excluding contractor parts supplied to Systron and Donner) will be performed by GSFC.

4.2.4.1

Parts - The parts program shall meet the requirements of GSFC Specification S-311-80, "Parts Program Requirements for GSFC Spaceflight Projects." The parts program plan shall be submitted as a section of the Reliability Plan. Additions and clarifications to S-311-80 are as follows:

- o A Program Authorized Parts List (PAPL) shall be maintained by the contractor. The list shall identify part types planned for use in the mission unique flight equipment. The format shall contain the information specified in Paragraph 3.7 of S-311-80 except that quantities may be omitted. Qualification status and source of qualifications

(i.e., MIL-STD-975, GSFC PPL-14, previous NSPAR, other government approvals, NSPAR required) shall be indicated. A preliminary PAPL shall be included in the Parts Plan. Monthly updates shall be submitted to GSFC.

- o A Contractor Approved Parts List (APL), proposed as an alternative to MIL-STD-975 and the GSFC PPL for part selection, shall be subject to approval/disapproval by GSFC prior to contract award. Upon request, qualification data and part specifications for parts not on MIL-STD-975 and the GSFC PPL shall be submitted for evaluation prior to acceptance of the contractor APL (Ref: Paragraph 3.2.b).
- o Alternate derating policies proposed by the contractor shall be subject to approval/disapproval by GSFC prior to contract award (Ref: Paragraph 3.2.c).
- o Part failure analyses shall be performed by GSFC on parts which fail at the contractor's and sub-contractor facilities, exclusive of part failures in the Wide Band Communication System (a) during qualification test and (b) during component level and higher assembly and test. Parts which fail during board or module tests shall be failure analyzed when the failure has been clearly isolated to the part (Ref: Paragraph 3.11).

For project and system detailed design reviews, the following shall be completed and the results summarized in the (Review) Data Package:

- o all nonstandard parts approval request actions
- o hybrid design reviews
- o incoming inspection and screening rejection histories
- o significant construction analyses findings
- o parts identification lists (recommended format included in Section 4.7.

o program authorized parts list (current)

4.2.4.2

Materials and Processes - The contractor shall implement a materials control program which shall stress the selection and application of materials and processes proven by appropriate test or similar spaceflight experience. Materials usage shall consider cleaning agents, solvents, and other materials used to clean and otherwise service the hardware. The contractor is responsible for controlling and ensuring the use of acceptable materials and processes. GSFC will review the contractor's materials program to ensure compliance. (Formats for materials and lubricants lists are included in Section 4.7)

Note: Materials used in the Angular Displacement Sensor Assembly shall be a GSFC responsibility.

For organic materials, NASA NRP 1014, "Out-gassing Data Compilation of Spacecraft Materials," shall be used as a selection guide. Materials meeting the 1.0 percent mass loss and 0.10 percent condensable materials are generally acceptable. Use of nonmagnetic materials shall be encouraged. Bearings, gears, lubricants, surface finishes shall be carefully chosen with the final choice being dictated by speed, load, temperature, operating lifetime, and contamination. GSFC materials technology report MTR 313-003, "An Evaluation of Liquid and Grease Lubricants for Spacecraft Applications," dated December 1976, may be used as a guide in the selection of lubricants.

All materials shall be procured to a military/NASA specification or to one controlled by the mission contractor. At the time of the detailed design review, all materials selections and materials qualification testing shall be identified. Modifications shall be submitted monthly.

The contractor shall use documented, controlled processes and trained, certified personnel for all operations which may impact the reliability or quality of the product.

Particular attention will be paid to those processes which may degrade the engineering properties of metallic structures. Manufacturing processes that result in improper control of the integrity of materials shall be avoided. Critical processes, such as coatings to metallic and optical surfaces, potting, and conformal coating, shall be identified in the Reliability Program Plan with regard to the application.

4.2.5

Failure Reporting and Corrective Actions - The contractor shall employ a closed loop system of nonconformance control and problem/failure reporting to meet the requirements of Paragraph 1A306 of NHB 5300.4(1A) and Chapter 8 of NHB 5300.4(1B). All nonconformances and failures shall be categorized, documented, and controlled regarding analysis, disposition, and corrective action in accordance with Table 4.3.7-1. Functional problems and failures at the component level and higher shall be considered major nonconformances subject to formal failure reporting, analysis, and corrective action starting with the first power application or mechanical operation. Major nonconformances shall be reported on GSFC Form 4-2, GSFC Malfunction Report, or an equivalent contractor form (reference Section 4.7). The contractor's system for dispositioning nonconformances of different categories shall clearly define the responsibilities of the Material Review Board and other organizations such as Test Review Boards or Failure Review Boards (reference Paragraph 4.3.7). Initial problem/failure reports shall be provided to GSFC or its designated representative within 48 hours of the occurrence. Prior to entering component or higher level acceptance/qualification tests, open failures or nonconformances shall be reviewed and understood regarding the potential impact on the test.

4.3

PRODUCT ASSURANCE REQUIREMENTS - FLIGHT SEGMENT

4.3.1

General - This subsection establishes the Product Assurance requirements for the Landsat-D system.

The contractor shall make specific personnel assignments to implement each element of the Product Assurance Program. Assignments shall include a specific Product Assurance Manager with direct access to higher management. Documented training programs shall be available for certification of all Product Assurance Program personnel as necessary.

The contractor shall report the status of the Product Assurance Program and shall perform scheduled and unscheduled internal audits and reviews of personnel, procedures, and operations relevant to the Project Assurance Program.

4.3.2

Design and Development Control - Design and development controls include technical documentation review, design review support, and control of documentation changes and change distribution.

Product Assurance personnel shall ensure that requirements are clear and unambiguous, and that necessary inspection and test criteria are specifically defined.

The contractor shall control distribution of change documentation and removal of obsolete documents from operational areas. Effectivity shall be clearly specified and the affected hardware appropriately identified.

4.3.3

Identification and Data Retrieval - The contractor shall develop and maintain an identification and data retrieval system for articles and materials and provide means for traceability of articles and materials.

Procedures shall be established to ensure that individual articles and materials or lots thereof are properly identified by a unique part, type number, or lot number.

4.3.4

Procurement Control - The contractor's Product Assurance personnel shall participate in the selection of procurement sources and shall schedule and conduct appropriate post-award surveys of suppliers. A supplier rating system shall be maintained to aid in the selection of procurement sources based on receiving inspection and test records.

The contractor's Product Assurance personnel shall review all procurement documents issued by the contractor and shall provide technical assistance and training to suppliers to ensure compatibility of inspections and tests with contractor requirements.

The contractor shall perform source inspection at subcontractor or suppliers' facilities, based on the hardware procurement, to ensure compliance with applicable requirements.

The contractor shall maintain a receiving inspection system for articles and materials to verify supplier documentation, accomplish inspections and tests, and provide a system for nonconformance feedback to suppliers to prevent recurrences.

4.3.5

Fabrication Controls - The contractor shall maintain article and material controls to prevent quality degradation and to ensure that nonconforming articles and materials are removed from work operations.

The contractor shall maintain process controls, cleanliness controls, and workmanship standards for all operations which may impact the quality of the product.

Soldering processes shall be to NHB 5300.4(3A-1), "Requirements for Soldered Electrical Connections."

4.3.6

Inspection and Tests - The contractor shall implement an inspection and test program which demonstrates that contract, drawing and specification requirements are met.

Mandatory inspection points shall be incorporated to verify that these requirements have in fact been satisfied. These are identified in Table 4.3.6-1.

Table 4.3.6-1
Mandatory Inspection Points

Parameter to be verified	Hardware/Test Level*	Contractor Inspection Requirements	Nominal Government Inspection Requirements*
1. Physical parameters that cannot be verified later without physical disassembly	All	Inspect	Monitor, audit, and selected inspections
2. Pre- and post-test operations	Module or card	Inspect	Monitor and Audit
	Assembled black box and spacecraft	Inspect	Witness
3. Performance, environmental, functional, and integration tests	Module or card	Monitor and audit**	Monitor and audit
	Assembled black box and spacecraft	Witness**	Witness
4. Handling and transportation activities	Assembled black box and spacecraft	Witness/inspect	Monitor and audit

*The frequency and number of government inspection points may be increased where the government monitor and audit program uncovers deficiencies in the contractor's inspection process.

**In-process tests shall be documented for all items by the testing organization. Quality assurance shall monitor or witness as shown.

The following definitions apply to this table:

- o Inspect - To verify compliance by physical examination.
- o Witness - To verify by personal observation on a 100% basis
- o Monitor - To verify by personal presence on a sampling basis
- o Audit - A formal examination and review of documentation

4.3.6.1

Manufacturing Inspection and Test - Inspection points shall be included on flow charts as part of the contractor's Product Assurance Program Plan, which show fabrication, processing and assembly operations, the associated inspection points, and the controlling documentation. The sequence of the flow charts shall start with the point of entry of purchased materials, parts, components, and GFE and conclude with the acceptance test and inspection of an assembled electrical, mechanical, or structural item (including GFE) being delivered to integration.

Formal documentation including assembly log books shall be used to control and record the flow of all hardware at all times. For mission-unique hardware, shop travelers shall be used and shall become a part of the log book for an assembled black box or mechanical component. These log books in turn shall become a part of the Flight Segment log book when the black box or component is integrated onto the Flight Segment. Log books shall be used to document and control all movements, storage, tests, and other activities of GFE while it is under contractor control.

4.3.6.2

System Integration and Test - The inspection and test program shall include a system for controlling integration and test requirements at the Flight Segment level and provide the visibility necessary to manage the overall test program and ensure and/or maintain the integrity of the hardware at all times. The system shall be described in the Product Assurance Program Plan and shall cover the following activities during:

- o Structural/dynamic model assembly and test
- o Flight model mechanical assembly
- o Electrical integration and test
- o Mechanical functional tests
- o Environmental and performance tests
- o Launch operations

The activities to be considered shall include test procedure preparation and revision; failure reporting and control; test records, reports, and log book preparations; test monitoring; cleanliness and contamination control; control of work activities, including troubleshooting, configuration definition and verification; and safety.

Integrated flow chart(s) compatible with the environmental test requirements of Paragraph 3.2.6 shall be submitted with the Plan referencing all pertinent activities starting with functional testing at the assembled component level or an item of structure being integrated onto the Flight Segment and continuing up through the final launch preparations.

4.3.7

Nonconforming Article and Material Control -

The contractor shall perform appropriate examinations, classifications, and analyses of nonconforming articles, materials, or conditions as shown in Table 4.3.7-1 to determine the cause or reason for the nonconformance. The contractor shall conduct timely remedial and preventative actions and assign responsibility for follow-up of the remedial and preventative actions to ensure accomplishment. Appropriate documentation of analyses and remedial and preventative actions shall be prepared.

Nonconforming articles or materials shall be reviewed initially by contractor Product Assurance personnel and shall be subjected to one of the following dispositions:

- a. Return for rework or completion of operations
- b. Scrap
- c. Return to supplier
- d. Submit to Material Review Board (MRB) for determination of final disposition.

Contractor requests to use as is, or to repair nonconforming articles, which adversely affect the basic objectives of the Landsat-D system, must be submitted in writing to the GSFC Contracting Officer for approval or rejection. Such articles and materials shall be withheld from use until the required approval is obtained.

4.3.8

Metrology Controls - The contractor shall establish and utilize a documented metrology system to control measurement processes in accordance with Chapter 9 of NHB 5300.4(1B).

Table 4.3.7-1
Nonconformance Control and Failure Reporting

Category	Description	Hardware	Approval Authority	
			Contractor	GIA* GSFC
Minor	1. Part parameter performance variations	Mission-unique, part level	X	Review Audit
	2. Cosmetic	Mission-unique, module and printed-circuit-board level	X	Review Audit
	3. Workmanship, form, fit			X Audit
	4. Function	Mission-unique, board or module	X	Review
Major	1. Workmanship, form, fit	Mission-unique components, assembly, and integration of flight segments		X Review
	2. Function	Mission-unique components, integration, and tests of flight segment		Review X
	3. Function	GFE		Review X

*GIA representation on the Material Review Board.

4.3.9

Stamp Controls - The contractor shall establish and maintain a documented stamp control system, including written procedures, which provide:

- o point of progress of articles and materials (and associated records) through the fabrication, inspection, and test
- o stamp traceability to each individual responsible for its use

4.3.10

Handling, Storage, Preservation, Marking, Labelling, Packing and Shipping - The contractor shall maintain and control the integrity of all hardware during all handling/storage/marking/shipping/transportation activities. The protection of articles and materials shall be achieved through the use of well designed and tested handling equipment and techniques, selection and controlled usage of acceptable packaging material and documented procedures and controls. Shipping requests shall show evidence of approval for shipment by the contractor's Product Assurance personnel and that the special procedures, instructions, and check lists have been issued and are available in the shipping area when required. Shipping instructions/procedures shall show evidence of compliance with stated instructions. A documentation package containing material required to identify, maintain, preserve, and utilize the shipment shall be submitted.

4.3.11

Sampling Plans, Statistical Planning and Analysis - Sampling plans may be used when inspections or tests are destructive; or data, inherent characteristics, or the noncritical application of an article or material indicate that a reduction in inspection or testing can be achieved without jeopardizing achievement of quality, reliability, or design intent. All sampling phases require the approval of the GSFC or its designated Government Product Assurance representative.

Statistical planning and analysis may be used where such use will provide effective control over fabrication and inspection operations, especially in those areas where special processes and equipment are difficult to control.

4.3.12

Government Property Control - The contractor is required to account for, maintain, and control the integrity of all Government Furnished Equipment (GFE) and Government Furnished Property (GFP). He shall segregate and report, in accordance with Government procedures, any GFE/GFP found damaged, malfunctioning or otherwise unsuitable for use as soon as the fact is known. Log books will be used to document and control all movements, storage, and tests, of GFE while it is under his control. GSFC approval will be required for all cover removals or any other entries into GFE flight hardware. GFE/GFP shall not be dispositioned, repaired, reworked, replaced, or in any way modified unless authorized by GSFC. The contractor shall prepare procedures based on GSFC-supplied data for moving, energizing, or operating flight GFE/GFP.

4.4

PRODUCT ASSURANCE REQUIREMENT - GSE

4.4.1

Flight Segment Level GSE - Product assurance requirements for GSE that interface with the Flight Segment or that are used to control the Flight Segment during integration and test shall be as specified in Section 4.5, Product Assurance Requirements - Ground Segment, of this document with the following exceptions:

- (1) equipment subject to thermal vacuum exposure with the Flight Segment shall meet flight requirements for outgassing materials;
- (2) parts and devices subject to thermal vacuum exposure shall be suitable for extended operation under vacuum and temperature extremes; and
- (3) demonstrations and acceptance tests of Paragraph 4.5 shall be performed at the contractor's facility

4.4.2

Handling Fixtures and Transportation - GSE - Major handling fixtures and transportation equipment shall be defined by design specifications. Configuration for this type of GSE shall be controlled by formal released drawings and be subject to change control after proof testing.

4.4.3 Other GSE - Other GSE shall be designed and fabricated consistent with good commercial practice.

4.5 PRODUCT ASSURANCE REQUIREMENTS - GROUND SEGMENT

The contractor shall plan and implement a Product Assurance Program for the Ground Segment equipment. The program shall start with the design phase and continue through demonstration and acceptance at GSFC.

4.5.1 Design and Development

4.5.1.1 Existing Equipment - Selection of existing equipment (off-the-shelf) shall be reviewed to assure an acceptable reliability and maintainability status compatible with a ten year useful life. Supplier design and manufacturing practices shall support high grade workmanship and ease of maintenance.

4.5.1.2 New/Modified Design Equipment - Equipment of new design or significantly modified design shall be subject to formal internal design review and documentation by the contractor. MIL-STD-975 and PPL-14 (Grade 2) shall be used as a guide in parts selection. Commercial parts with a satisfactory reliability history are acceptable. Design and manufacturing practices shall support high grade workmanship and ease of maintenance.

4.5.1.3 Specifications - Contractor prepared or contractor approved supplier specifications shall be established for each system, subsystem, or component of the Ground Segment. Performance, function, interface, and physical configuration shall be defined.

4.5.1.4 Reliability Analyses - Contractor personnel shall review the OCC system to assure that adequate provisions are incorporated in the design to preclude single point failure. FMEA studies shall be performed, as well as a determination of MTBF & MTTR values, for the Ground Segment and its major functional paths.

4.5.1.5 Design Documentation - Engineering technical documentation defining the Ground Segment equipment and software shall be subject to a formal release system and subsequent change control prior to delivery to GSFC for installation.

- 4.5.1.6 GSFC Reviews - The contractor shall support GSFC Project Office design reviews covering subsystems of the Ground Segment during the design and development phase. The contractor shall present detailed Design and Flight Readiness Reviews covering Ground Segment systems to a GSFC Centerwide team (reference Paragraph 4.2.2.3).
- 4.5.2 Procurement Controls - The contractor shall implement procurement controls to review purchase orders for adequate technical and quality requirements, to control changes and nonconformances, to define acceptance inspection and tests, and to provide suitable quality documentation.
- 4.5.3 Fabrication Controls - New and modified equipment designs shall be manufactured to controlled processes and workmanship standards defining high grade practices.
- 4.5.4 Inspection and Test - Fabrication and assembly operations shall be accomplished to quality approved planning documentation. Verification inspections shall be on a sample basis with discrepancies and rework indicated. Quality surveillance shall be maintained during installation of equipment at GSFC and a quality buy-off inspection performed at completion of appropriate component, subsystem, and system level installations. Final acceptance simulations and demonstrations shall be performed to released procedures and shall be witnessed by quality assurance personnel.
- 4.5.5 Nonconformance Control - A documented nonconformance control system, under contractor control, shall be implemented for the fabrication, assembly, and test, through initial installation at GSFC. For the subsystem and system level shakedown, simulation, and demonstration phase, a formal problem report/corrective action program, including GSFC participation, shall be initiated.

4.5.6

Software Management and Control - The contractor shall prepare and implement development plan for both the Flight Segment and the Ground Segment Software for the Landsat-D program. These plans shall define the specific activities, tasks, management policies and controls, including quality assurance provisions, for the software development effort. The plans shall provide guidelines for software engineering in the design, implementation, and test of the software systems. The Flight Segment and Ground Segment software management plans shall be submitted to the GSFC for review and approval prior to implementation.

4.6

SYSTEM SAFETY REQUIREMENTS FOR LANDSAT-D

The contractor shall plan and execute a systems safety program directed toward the protection of the development and flight hardware and protection of property and personnel from hazards associated with the development, test, launch, and retrieval of flight hardware and ancillary equipment. The systems safety effort shall interface efficiently with industrial safety and public safety requirements of the contract. It shall emphasize early effort to identify hazards associated with the development, assembly, test, handling, transportation, launch and flight use of the hardware, and necessary steps during the project effort to eliminate or control hazards. The contractor shall comply with the requirements of the document specified in Paragraph 2.2.2.2, and 2.2.2.3 for all range operations and with the document specified in Paragraph 2.1.8.2 for a Shuttle launch or retrieval, except that the Mission System Ground Safety Approval Package (MSG SAP), and the STS Safety Analysis in accordance with NHB 1700.7A will be performed by the GSFC. Tasks under the system safety program are as follows:

4.6.1

Systems Safety Plan - The contractor shall provide and implement a systems safety plan for the Landsat-D program which defines all safety activity and specific tasks for the contract effort. The safety plan shall be submitted for GSFC review and approval in accordance with Paragraphs 4.1.2.3, 2.2.2.7, and 2.2.2.8. It shall contain the contractor's approach, logic, task breakdown, organization and responsibilities for the systems safety effort. It shall also clearly define all interfaces in the safety areas.

4.6.2

System Safety Management - The contractor shall designate an individual responsible for managing the system safety program. The Systems Safety Plan shall define his responsibilities and organizational relationships to other elements of the contractor's organization performing interrelated safety efforts.

4.6.3

System Program Interfaces - The contractor shall provide well defined and efficient interfaces between the systems safety effort and other safety efforts of the contractor and of the Government. These shall be clearly described in the Systems Safety Plan, with particular attention to the following:

- (1) In-plant industrial safety
- (2) Public safety
- (3) Launch site and WTR range safety
- (4) Support of STS safety requirements

4.6.4

Safety Analyses - As early as practical in the contract effort, the contractor shall develop analyses identifying hazards from the project hardware and hazards which may damage the hardware. The analysis shall also indicate likelihood of occurrence and potential consequences of incidents or accidents resulting from the identified hazards. These analyses shall support the requirements of documents specified in Paragraphs 2.2.2.3 for Delta missions, and comply with 2.2.2.7 for basic safety requirements. The first complete iteration of these analyses shall be provided to GSFC in the data package for the Detailed Design Review (DDR) and updated versions shall be provided similarly for the Pre-Environmental Review and Launch Readiness Review. Specific plans and summary analyses shall be submitted as required by the contract schedule.

GSFC will be responsible for shuttle safety analyses. However, the contractor shall provide information, as required, to support these GSFC analyses. The results of the GSFC analyses will be coordinated with the contractor to determine impact on the Landsat-D design and operational plans and any corrective measures required.

4.6.5

Hazard Reduction and Control - The contractor shall take measures as necessary to minimize and/or control each significant identified hazard. These measures should be applied in the following order of priority:

- (1) design to eliminate the hazard;
- (2) apply automatic safing controls;
- (3) apply automatic warning devices; and
- (4) use procedural steps to control the hazard

The measures planned and implementation steps taken for reduction/control of each identified hazard shall be described at the DDR. This description shall include a presentation of the rationale underlying the reduction/control measures selected in each case. As hazard analysis effort is updated throughout the project life, appropriate control efforts shall be planned and implemented. Status of all hazard reduction/control effort shall be reported at the Pre-Environmental Review and the Launch Readiness Review.

4.6.6

Safety Training and Certification - The contractor shall identify in his Systems Safety Plan such requirements for special personnel safety training, certification, and motivation as he considers necessary.

4.6.7

Safety Audits - The contractor shall conduct system safety audits of operations under his jurisdiction including those of subcontractors and suppliers. His plan and schedule for this auditing effort shall be included in the system safety plan.

4.6.8

Incident Reporting - Any injury, accident, or incident resulting from a hazard shall be reported to GSFC no later than 15 days after any such occurrence.

RELIABILITY AND PRODUCT ASSURANCE SAMPLE FORMS
AND LISTS

This section contains sample copies of the following forms and lists:

- o Figure 4.7-1 - Spacecraft Lubrication List
- o Figure 4.7-2 - Spacecraft Inorganic Materials List
- o Figure 4.7-3 - Spacecraft Polymeric Materials List
- o Figure 4.7-4 - Spacecraft Materials Processes List
- o Figure 4.7-5 - Parts Abstract List
- o Figure 4.7-6 - GSFC Malfunction Report
- o Figure 4.7-7 - Documentation Deliverable List

[illegible]

Figure 4.7-1. Spacecraft Lubrication List (Sheet 1 of 2)

NOTES

- (1) BB = ball bearing, SB = sleeve bearing, G = gear, SS = sliding surfaces, SEC = sliding electrical contacts. Give generic identification of materials used for the component, e.g., 440C steel, PTFE.
- (2) CUR = continuous unidirectional rotation, CO = continuous oscillation, IR = intermittent rotation, IO = intermittent oscillation, SO = small oscillation ($<30^\circ$), LO = large oscillation ($>30^\circ$), CS = continuous sliding, IS = intermittent sliding.
No. of wear cycles: A($1-10^2$), B(10^2-10^4), C(10^4-10^6), D($>10^6$)
- (3) Speed: RPM = revs./min., OPM = oscillations/min., VS = variable speed
CPM = cm/min. (sliding applications)
Temp. of operation, max. & min., $^\circ\text{C}$
Atmosphere: vacuum, air, gas, sealed or unsealed & pressure
- (4) Type of loads: A = axial, R = radial, T = tangential (gear load). Give amount of load.
- (5) If BB, give type and material of ball cage and number of shields and specified ball groove and ball finishes. If G, give surface treatment and hardness. If SB, give dia. of bore and width. If torque available is limited, give approx. value.
- (6) Evaluator's comments to be filled in by GSFC evaluator. A = approved, NA = not approved, SA = see attached document for further comments.

SPACECRAFT _____ GSFC SPACECRAFT INORGANIC ⁽¹⁾ MATERIALS LIST _____ GSFC T/O _____ CONTRACTOR _____ SYSTEM/EXPERIMENT _____ PREPARED BY _____ ADDRESS _____ PHONE _____ DATE PREPARED _____ GSFC MATERIALS EVALUATOR _____ PHONE _____ DATE RECEIVED _____ DATE EVALUATED _____					
ITEM NO	MATERIAL IDENTIFICATION ⁽²⁾	CONDITION ⁽³⁾	APPLICATION ⁽⁴⁾	EXPECTED ENVIRONMENT ⁽⁵⁾	GSFC EVALUATION ⁽⁶⁾
					A NA SA

See reverse side for notes

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Figure 4.7-2. Spacecraft Inorganic Materials List (Sheet 1 of 2)

NOTES

- (1) List all inorganic materials (metals, ceramics, glasses, liquids) except bearing and lubrication materials which should be listed on form GSFC 18-59C.
- (2) Give name of material, identifying number, manufacturer.
 E.g., Aluminum 6061-T6
 Electroless nickel plate, Enplate Ni-410, Enthone, Inc.
 Fused silica, Corning 7940, Corning Glass Works.
- (3) Give details of the finished condition of the material, heat treat designation (hardness or strength), surface finish and coating, cold worked state, welding, brazing, etc.
 E.g., Heat treated to R_c 60 hardness, gold electroplated, brazed
 Surface coated with VDA and MgF_2
 Cold worked to Full Hard condition and welded by TIG process, electroless nickel plate.
- (4) Give details of where on the spacecraft the material will be used (component) and its function.
 E.g., Electronics box structure in attitude control system, not hermetically sealed.
- (5) Give the details of the environment the material will experience as a finished S/C component, both in ground test and in space. Exclude vibration environment. List all materials with the same environment in a group.
 E.g., T/V: $-20^\circ C/+60^\circ C$, 2 weeks, 10^{-5} torr, UV
 Storage: up to 1 year at RT
 Space: $-10^\circ C/+20^\circ C$, 2 years, 150 mi. alt., UV, electron, proton
- (6) Evaluator's comments to be filled in by GSFC evaluator. A = approved, NA = not approved, SA = see attached document for further comments.

NOTES

- (1) List all polymeric (organic) materials total systems except lubrication materials which should be listed on form GSFC 18-59C.
- (2) Give name of material, identifying number, manufacturer.
E.g., Epoxy, Epon 828, Shell Chem., Co.
- (3) Provide proportions and name of resin, hardener (catalyst), filler, etc.
E.g., 828/V140/Silflake 135 as 5/5/38 bwt.
- (4) Provide cure cycle details.
E.g., 8 hrs @ RT + 2 hrs @ 150°C
- (5) Provide the details of the environment the material will experience as a finished S/C component, both in ground test and in space.
Exclude vibration environment. List all materials with the same environment in a group.
E.g., T/V: -20°C/+60°C, 2 weeks. 10⁻⁵ torr, UV
Storage: up to 1 year at RT
Space: -10°C/+20°C, 2 years, 150 mi. alt., UV, electron, proton
- (6) Provide any special reason(s) why the material was selected. If for a particular property, please give the property.
E.g., Cost and availability
RT curing and low expansion
- (7) Evaluator's comments to be filled in by GSFC evaluator. A = approved, NA = not approved, SA = see attached document for further comments.

[illegible]

Figure 4.7-4. Spacecraft Materials Processes List (Sheet 1 of 2)

NOTES

- (1) Give generic name of process, e.g., anodizing (sulfuric acid).
- (2) If process is proprietary, please state so.
- (3) Identify the type and condition of the material subjected to the process.
E.g., 6061-T6
- (4) Identify the component or structure of which the materials are being processed.
E.g., Antenna dish
- (5) Evaluator's comments to be filled in by GSFC evaluator. A = approved, NA = not approved, SA = see attached document for further comment.

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310-22 (2/72) SHADED AREAS ARE FOR DATA GROUP USE ONLY.

4-35

GSFC MALFUNCTION REPORT

noF 02040

(1) Project										(2) Spacecraft										(3) Operation										(4) Units																													
(5) System or Experiment										(6) Date & Time of Malfunction										(7) Date of Report										(8) Critical																													
NAME										IDENTIFICATION NUMBER										SERIAL NUMBER										MANUFACTURER																													
(9) Component																																																											
(10) Assembly																																																											
(11) Sub-Assembly																																																											
(12) Part										Manufacturers Part Number																																																	
(13) Malfunction Occurred During										<input type="checkbox"/> 1 Qualification Test <input type="checkbox"/> 2 Acceptance Test										<input type="checkbox"/> 3 Integration Test <input type="checkbox"/> 5 Launch Operations										<input type="checkbox"/> 7 Bench Test <input type="checkbox"/> 8 Post Launch																													
(14) Environment When Failed										<input type="checkbox"/> 1 Acceleration <input type="checkbox"/> 2 Shock										<input type="checkbox"/> 3 Thermal-Vacuum <input type="checkbox"/> 4 Temperature										<input type="checkbox"/> 5 Humidity <input type="checkbox"/> 6 Vibration										<input type="checkbox"/> 7 Ambient <input type="checkbox"/> 8 Acoustic										<input type="checkbox"/> A RFI/EMC <input type="checkbox"/> 0 Vacuum									
(15) Hardware Level When Failed										<input type="checkbox"/> 1 Part <input type="checkbox"/> 2 Sub-Assembly										<input type="checkbox"/> 3 Assembly <input type="checkbox"/> 4 Component										<input type="checkbox"/> 5 System <input type="checkbox"/> 6 Spacecraft																													
(16) REFERENCE																																																											
Spacecraft Log Book # _____ Page _____ Test Procedure _____ Para _____																																																											
(17) Description of the Malfunction:																																																											
(18) Originator: _____ Phone: _____ Organization: _____																																																											
Do Not Write in This Space																																																											
(19) Cause of the Malfunction:																																																											
(20) Corrective Action Taken:																																																											
If Corrective Action is Required on Other Units, List Units by Serial No.																																																											
Do Not Write in This Space																																																											
(21) Failure Analysis Performed?										YES NO										Organization That Performed Failure Analysis										Date																													
										<input type="checkbox"/> 1 <input type="checkbox"/> 2										Failure Analysis Report Number																																							
(22) Action Taken on Failed Unit										<input type="checkbox"/> 1 Rework/Repair <input type="checkbox"/> 2 Modified <input type="checkbox"/> 3 Discarded <input type="checkbox"/> 4 Replaced <input type="checkbox"/> 5 None										Organization That Performed Rework/Repair										Date																													
(23) Is Retest Required?										<input type="checkbox"/> 1 Yes <input type="checkbox"/> 2 No										If Yes, State Retest Requirements																																							
(24) Retest Results										Satisfactory Unsatisfactory										Remarks:																																							
										<input type="checkbox"/> 1 <input type="checkbox"/> 2																																																	
(25) Unit May Be Used For										Flight Test Only																																																	
										<input type="checkbox"/> 1 <input type="checkbox"/> 2																																																	
Yr Mo Day										Date MR Closed										GSFC Project Approval										Date										Contractor Approval										Date									

GSFC 4-2 (11/76)

Figure 4.7-6. GSFC Malfunction Report (Sheet 1 of 2)

INSTRUCTIONS FOR ENTERING DATA ON GSFC MALFUNCTION REPORT

General - This malfunction report form is to be used as a working document as well as a means of recording information that can be stored and later retrieved. Information shall be filled in each block from left side to right except for the block titled "Serial Number" under items (9) through (12). These shall be filled in from right side to left. All applicable information shall be recorded.

Detail

- Item (1) - Enter project name.
- Item (2) - Enter spacecraft identification.
- Item (3) - Enter operations. If hours, to tenth of hour. If cycles, to cycle.
- Item (4) - Check block to designate proper units for item (3).
- Item (5) - Enter system or experiment name. Definition "System" - The next functional subdivision of a spacecraft, and is generally composed of two or more components designed to perform an operation. Example: Electrical system, Communication system, Stabilization and Control system, etc. "Experiment" - The next functional subdivision of a spacecraft and is generally a combination of two or more components, including both the sensor and associated electronics designed for acquisition of data for space research.
- Item (6) - Enter date & time of malfunction. Example - June 8, 1967 at 3 p.m. - Year 67, Month 06, Day 08, Time 1500.
- Item (7) - Enter date the malfunction report is originated. Example June 9, 1967 - Month 06, Day 09 - Year will be determined from Item (6).
- Item (8) - To be filled in by GSFC Project Office.
- Item (9) - Enter component name. Definition "Component" - The next functional subdivision of a system and generally is a self-contained combination of assemblies performing a function necessary to the system's operation. Example: Power supply, transmitter, gyro package, etc. Enter component identification no., serial no., and the manufacturers name.
- Item (10) - Enter assembly name. Definition "Assembly" - The next functional subdivision of a component and consist of parts or subassemblies which perform functions necessary to the operation of the component as a whole. Example: Regulator assembly, Power Amplifier assembly, Gyro Assembly, etc. Enter the assembly identification no., serial no., and manufacturers name.
- Item (11) - Enter subassembly name. Definition "Subassembly" - An assembly within a larger assembly - Example: Wired printed circuit board, modules, etc. - Enter subassembly identification no., serial no., and manufacturers name.
- Item (12) - Enter part name. Definition "Part" - An element of a component, assembly or subassembly which is not normally subject to further subdivision or disassembly without destruction of designed use. Example: Resistors, transistors, diodes, etc. Enter manufacturers part number, and the manufacturers name.
- Item (13) - Check block that defines the type of test that was being conducted when malfunction occurred. If the type of test was other than those listed defined type of test in Item (17).
- Item (14) - Check block that defines the actual environment the unit was being subjected to when the malfunction occurred. Caution - for an example do not check vibration if unit failed during a functional test prior to the actual application of the vibration environment, check ambient. If the environment in which the unit failed is not listed or the description listed does not give sufficient detail give this information in Item (17).
- Item (15) - Check block that defines the hardware level at the time of failure. For example - if a power supply subassembly fails during Communications system test, check system.
- Item (16) - Enter reference information.
- Item (17) - Enter all details of the malfunction such as; inputs, outputs, tolerances, symptoms, abnormal conditions, testing phase, detail of environment and prior environment, etc.
- Item (18) - Print name, phone no. and organization.
- Item (19) - Enter detailed, but concise, narrative defining the direct cause of malfunction.
- Item (20) - Enter detailed, but concise, narrative defining the corrective action taken. The corrective action shall be sufficient to preclude the malfunction from occurring again. List other units affected by the corrective action. Enter N/A if not applicable.
- Item (21) - Check block to indicate if failure analysis was conducted. Give organization and report no. & date.
- Item (22) - Check block to indicate rework of failed unit. Give organization and date rework accomplished.
- Item (23) - Check block to indicate if retest is required. If required, state requirements.
- Item (24) - Check block to indicate test results.
- Item (25) - Check block to indicate future use of reworked unit.

Figure 4.7-6. GSFC Malfunction Report (Sheet 2 of 2)

Paragraph Reference	Item	Info.	Review	Appr.	Delivery Schedule
4.1.2	Reliability Plan			X	With proposal
4.1.2	Flight Segment Product Assurance Plans			X	With proposal
4.1.2	GSF Product Assurance Plan			X	With proposal
4.1.2	Ground Segment Product Assurance Plan			X	With proposal
4.1.2	Subcontractor and Supplier Reliability and Product Assurance Plans	X			Upon request
4.2.2, 4.6.1	Systems Safety Plan			X	With proposal
4.2.1	Reliability Progress Reports	X			With technical progress reports
3.2.6, 4.3.4.2	Flight Segment Environmental Test Specifications			X	Preliminary - With proposal Final - 90 days after contract award
4.2.2, 6.7 4.5.1.6	Design Review Data Packages		X		10 days prior to Project review 10 days prior to Systems review
4.2.3.1 4.5.4.4	FMEA		X		Include in conceptual/critical design review data
4.2.3.2, 4.2.3.3	Parts, Devices, and Materials Applications Reviews, including stress analysis, worst case tolerance analysis		X		Include in conceptual/critical design review data
4.2.4.1	Contractor's Program Authorized Parts List			X	With reliability plan
4.7.4.1	Modifications of Contractor's Program Authorized Parts List		X		Monthly
4.2.4.1	Contractor Derating Criteria			X	With reliability plan
4.2.4.1	Parts Identification List	X			Detailed design review
4.2.4.1	Nonstandard Part Approval Requests		X		10 Days after part identification
4.2.4.1	Part Qualification Test Plans and/or Reports		X		With MSPAR
4.2.4.1	Qualification Status Report	X		X	Monthly progress reports
4.2.4.1	Part Procurement Specs		X		Upon request and with MSPAR's
4.2.4.1	Construction Analysis Reports		X		As generated
4.2.4.1	Hybrid Microcircuit Chip Identification		X		With MSPAR
4.2.4.1	Part Screening Results	X			Upon request
4.2.4.1	ALERTS	X			As generated
4.1.1.3	ALERT Corrective action		X		Two weeks after ALERT issuance
4.2.4.2	Materials, Lubricants, and Processes Lists: and Modifications		X		Conceptual/Detailed Design Review Data Package; Modification Monthly
4.2.4.2	Materials and Process Specifications		X		As issued, and with MSPAR
4.2.5	Failure Reports - Analysis Corrective Action			X	As completed by contractor
4.2.5	Failure Report - Status Summaries	X			With technical progress reports
4.2.5	Failure Reports - Initial	X			Within 48 hours after failure
4.3.4	Subcontractor and Supplier Surveys	X			Upon request
4.3.6 4.4.1 4.5.4	Inspection and Test Procedures		X		Plane as issued PROC - 2 weeks before tests
4.3.7	Material Review Board Actions		X		Upon request
4.3.7 4.5.5	Waivers and Deviation Requests			X	As generated
4.5.6	Ground Segment Software Management Plan - GES 10097			X	October 1979
4.5.6	Software Quality Assurance Plan Ground Segment - GES 10099			X	October 1980
4.5.6	Software Configuration Management Plan Ground Segment - GES 10070			X	October 1980

Figure 4.7-7. Documentation Deliverable List (Sheet 1 of 2)

Paragraph Reference	Item	Info.	Review	Appr.	Delivery Schedule
4.6.3 (4)	Shuttle Analysis and Support Data			X	2 Mo. Prior to * Phase Reviews
4.6.4	Hazard Analysis and Updates		X		Design Review Packages or Applicable Safety Document
4.6.8	Injury/Accident/Incident Reports	X			15 days after occurrence
6.8.3	End-Item Data Package		X		With end item

*The Mission Systems Ground Safety approval package and the Shuttle analysis are tasks to be accomplished by the GSFC

Figure 4.7-7. Documentation Deliverable List (Sheet 2 of 2)

CONTRACTOR CONFIGURATION MANAGEMENT REQUIREMENTS

The contractor shall prepare a Configuration Management (CM) Plan that will control, identify, account, verify, and audit Flight Segment protoflight and flight hardware and software Configuration Items (CI's) and for ground segment hardware and software CI's based on the requirements specified in Paragraphs 2.2.2.4 and 2.2.2.10. The CM Plan shall provide for the establishment of a Configuration Control Board (CCB) at the contractor's facility which shall evaluate and approve all proposed changes prior to their implementation. The Landsat-D Project's CCB approval for Class I Changes, Critical/Major Deviations and Waivers is mandatory; all Class II Changes shall be submitted to the GSFC Technical Officer for review of classification. The definition of Class I and Class II changes shall be as specified in Paragraph 2.2.2.4. The CM Plan shall ensure that all affected parties are cognizant of baseline documentation and the impact of changes (technical, cost, schedule, weight, performance, reliability, etc.), and that baseline commitments and changes are implemented through applicable Government/contractor channels. At each appropriate Configuration Baseline, there shall be a verified detailed Configured Articles List (CAL). The CAL shall be maintained current by the contractor in enough detail to firmly identify and establish the current configuration of all CI's. The descriptive portions of the CAL shall include, but not be limited to: CI nomenclature; latest specification; updated engineering drawing numbers, including latest change date; applicable Interface Control Documents (ICD's); intended use; and actual location at time of listing. The contractor's proposed CM plan will be submitted for GSFC review and approval in accordance with Paragraph 4.1.2.3.

The plan submitted, which should be based on the contractor's existing CM system, must include:

a. Definition and description of:

- (1) CM organization, policies, procedures, and responsibilities, including contractor's definition of Class I and Class II changes; major and minor waivers and deviations.
- (2) Contractor's progressive baselining system, change release system, specification change control system, drawing control and release system, and system for incorporating changes, deviations, and waivers in baseline data.
- (3) Proposed levels of Configuration Identification, CI numbering system and levels of serialization, including proposed Configured Articles List format and content.
- (4) CI status accounting, change verification and closeout, and final configuration audit and verification systems.
- (5) Proposed procedures for maintaining GFE, GFP, or subcontractor CM interfaces as well as Flight Segment/Ground Segment CM interfaces.
- (6) Proposed procedures flows to obtain review or approval of changes, waivers, and deviations, and to implement such changes, waivers, or deviations after review or approval. Include projected time spans anticipated from initiation to implementation.

b. Copies of all proposed forms, reports, and lists, and copies of any contractor documents or procedures incorporated in the CM Plan by reference only.

6.0

DOCUMENTATION REQUIREMENTS

In this section, ground segment shall always apply to the DMS, LAS, OCC and TGS.

6.1

PLANS

The Landsat-D plans shall be specific, factual, and concise, to commit the contractor to specific courses of action, a level of performance, and a level of effort. For mission unique equipment, the contractor shall indicate any difference, if applicable in dealing with: new designs, modified designs, proven designs to be fabricated, off-the-shelf hardware used as is, and existing hardware to be modified or refurbished. Sufficient detail must be included to associate tasks with the responsible groups, and to permit a correlation among the contents of the plans, the Work Breakdown Structure, and the associated number of hours proposed for each task. All plans shall include a schedule showing the start and complete times keyed to significant project milestones for activities and documents referenced in the plan.

- o Protoflight Acceptance Test Plan. The protoflight acceptance test plan shall be in accordance with Paragraph 3.2.6.
- o Flight Acceptance Test Plan. The flight acceptance test plan shall be in accordance with Paragraph 3.2.6.
- o Flight and Operations Plan for OCC. This plan shall be in accordance with Paragraph 3.3.2.2.1 and 3.3.2.2.2.
- o DMS Test Plan. The DMS test plan shall be designed to verify the performance requirements given in Section 3.4.4
- o GS Operations Readiness Verification Test Plan. This test plan shall be in accordance with Paragraph 3.3.2.4.3.

- o Training Plan. The DMS, OCC and TGS training plan shall delineate the amount and level of training required for personnel and present a plan for providing the required training.
- o Manpower Requirements Plan. The DMS, OCC and TGS manpower requirements plan shall delineate the manpower requirements required for operation and support of the DMS, OCC and TGS.
- o Ground Segment Installation Plans. Detailed integration and installation plans for the DMS, OCC, and TGS shall be submitted.
- o Configuration Management Plans. Configuration management plans shall be consistent with Paragraph 5.0.
- o OCC Test Plan. The OCC test plan shall be prepared to verify the performance requirements given in Paragraph 3.3.2.
- o TGS Test Plan. The TGS test plan shall be designed to verify the performance requirements given in Appendix A.
- o Launch Operations and Orbital Operations inputs for the Network Operations Support Plan. Support NASA/GSFC in preparation of Network Operations Support Plan.
- o Mission System Activation Plan.
- o Mission Control and Operations Plan.
- o Flight Segment Evaluation Plan.
- o Data Processing Operations Plan.
- o Control Point Management Plans.
- o Ground Segment Acceptance Test Plans.
 - prelaunch Integration Test Plans
 - postlaunch Acceptance Test Plan

- o Production Control Plan.
- o Imaging Systems Performance Evaluation Plan.
- o Ground Segment Management Plan.
- o Operational Quality Assurance Plan.
- o Ground Segment Operational Configuration Management Plan.
- o Ground Segment Maintenance Plan.
- o Ground Segment Logistics Plan.
- o Flight and Ground Software Management Plans

The following flight assurance plans shall be in accordance with Paragraph 4.0:

- o Reliability Plan - Flight Segment
- o Product Assurance Plan - Flight Segment,
- o Product Assurance Plan - GSE
- o Product Assurance Plan - Ground Segment
- o Systems Safety Plan

6.2

SPECIFICATIONS AND REQUIREMENTS DOCUMENTS

- o Flight Segment Design Specification- Prepared in accordance with 1A301 of Paragraph 2.2.1.2.
- o Flight Segment Integration Test Specification - This specification shall be prepared in accordance with sections 1B702 and 1B703 of Paragraph 2.2.1.5, section 1A402 of Paragraph 2.2.1.2, and Paragraph 4.3.6 of this specification.
- o Support Instrumentation Requirements Document (SIRD) - Delineates the Landsat-D System operational requirements.

- o Ground Segment Design Specifications - Prepared in accordance with 1A301 of Paragraph 2.2.1.2 and Paragraph 4.5.4 of this specification.

- o Ground Support Equipment (GSE) and AGE/BTE Design Specifications - Prepared in accordance with 1A301 of Paragraph 2.2.1.2

- o Interface Specification Document - The contractor shall provide an Interface Specification Document (ISD). The ISD shall be updated by the contractor as required to keep the contents of the ISD accurate.

The ISD shall define the information needed by the Flight Segment contractor about the GFE instruments and GFE subsystems in order to effectively integrate these instruments and subsystems into the Flight Segment. It shall also provide a description of the Flight Segment bus, showing its capabilities, its limitations, its mechanical and electrical interface requirements, and the purpose behind the request for information. A program overview shall also be included to familiarize the Landsat-D Project personnel with the handling of instruments between delivery and launch.

- o Stage Release System - The Landsat-D program shall use a Stage Release System (4 stages) for dissemination of interface information to the Landsat Project. Each stage release shall require definition of the interface information required by the ISD. The contractor shall define the Stage Release System and its contents.

The mission contractor shall generate an Interface Specification Document identifying all of the the required interface information to be supplied by each contractor. The Flight Segment contractor shall generate final interface control documentation.

Stage I Release documents call for conceptual and estimated data. Dimensions are required with a ± 2.54 cm (1 inch) tolerance.

Stage II Release documents call for "preliminary first draft, best estimate" type of information. Typical dimensional tolerances are 1.27 cm (.5 inch).

Stage III Release documents call for "initial manufacturing tolerances, final draft, final agreements" type of information.

Stage IV Release documents call for final values for all items.

- o Design and Test Documentation - Documentation to be provided by the Flight Segment contractor shall include, but not be limited to the following:
 - a. Flight Segment Interface definition documentation for the instruments, subsystems, and launch vehicle.
 - b. Drawings (including current changes). This category consists of drawings at all levels, associated parts and materials lists, schematics, interconnection diagrams, and tables.
 - c. Flight Segment and subsystem acceptance test procedures and detailed test procedures including those at intermediate stages of assembly.
 - d. Ground Segment interface definition documentation which delineates the interfaces with GSFC and external operational support services.
 - e. Ground Segment acceptance and operational readiness test procedures.
 - f. Ground Segment Design Description. Describes Ground Segment configuration, data flow, and operational concepts.

- o Facilities Requirements Document (Ground Segment) - The contractor shall identify the facilities required for the OCC, DMS, and TGS equipment at the GSFC.

6.3

ANALYSES

Analyses shall be prepared for each of the interfaces, subsystems, and completed systems as appropriate. These analyses shall be submitted as part of the Design Review Packages (Paragraph 6.7).

6.3.1

Thermal Analyses. Thermal analyses shall be prepared to establish the thermal design required to meet the thermal performance requirements of Paragraphs 3.2.3.5, 3.2.4.2.1.2, 3.2.4.2.2.2, and 3.2.4.3.5. The thermal analyses shall be updated as required and shall consider all expected environments and worse case conditions.

6.3.2

Structural Analyses. Structural analyses shall be performed for flight model subsystems and the complete Flight Segment. The analyses shall be used to establish the mechanical design required to meet the performance requirements of Paragraphs 3.2.3.1, 3.2.4.2.1.1, and 3.2.4.2.2.1. As a part of the structural analyses, a dynamic analysis based on vibration math model(s) consistent with the performance requirements of Paragraphs 3.2.3.1, 3.2.4.2.1.1, and 3.2.4.2.2 shall be performed. The structural analyses shall be appropriate for all stress conditions of prelaunch handling, launch conditions, and on-orbit conditions, consistent with the minimum safety standards established for Paragraph 4.0.

6.3.3

System Design Phase. A structural analysis shall be performed to select a design from several options and to demonstrate the ability of this design to accomplish the Landsat-D Flight Segment mission objectives.

The structural analysis may be performed using classical analytic approaches; however, the recommended analytic approach is the use of a finite-element analysis implemented via computer program. As the primary means for demonstrating the acceptability of the design

and for reporting detail engineering information concerning the structure to the Landsat-D Project, the preferred program is the most recent version of the NASA Structural Analysis (NASTRAN) program, NASA's finite-element computer program. NASTRAN is officially released via: Computer Software Management and Information Center, Barrow Hall, University of Georgia, Athens, Georgia 30601. Structural analyses of the flight support structure for Shuttle and Delta are performed with NASTRAN. The task of evaluating structural compatibility between the Flight Segment and the FSS/Orbiter or the Delta will be accomplished through the use of NASTRAN.

6.3.4

Static-Load and Stress Analyses. The static-load and stress analyses of the Flight Segment shall be performed with NASTRAN. The model shall accurately represent the stiffness and mass of primary structural components and the mass of all significant nonstructural components. Good finite-element modeling practices shall be followed.

Thermal gradients and induced loads shall be considered in this phase of the stress analysis.

NASA shall provide, upon request, a NASTRAN finite-element model of the MMS including: a deck consisting of standard IBM 80-column punch cards created on an IBM 029 keypunch and, upon request, an unlabeled tape, 9-track, 800 bits per inch with card images; listing; test case; plots of the model; description of the modeling approach, boundary conditions, loads, and other pertinent features; and guidelines for adding to the model. This model shall be used as a basis of a detail model of the subsystem module which represents accurately the subsystem components for both static and dynamic analyses.

Design loads and/or combinations of design loads, defined for critical loading conditions of ground, launch, orbit, and reentry phases of the payload program, shall be applied as static loads to the structure. Resultants of loads, stresses, and deflections of primary structures shall be used to demonstrate the compliance of the design with the requirements of Section 3.2. The static-load and stress

analyses shall be used to (1) define or demonstrate the load distribution taken by principal structural loads transmitted through the structure, (2) optimize the arrangement and sizes of specific structural components by comparing the results of various design options, and (3) report engineering parameters of significant structural components; e.g., load, margin of safety, stress, and deflection.

A completed NASTRAN model and analysis of the entire Landsat-D Flight Segment Module shall be delivered to NASA.

6.3.5

Dynamics Analyses. The dynamic characteristics of the selected design shall be investigated through a dynamic NASTRAN model. The dynamic model may be (1) the static model, (2) the result from a reduction of the static model, or (3) a remodeling of the structure for dynamic analysis. The mission contractor may use the dynamic model to perform a vibration-test simulation to aid in the instrument module design and testing. For the frequency range of up to 100 Hz, the dynamic model shall be used by GSFC to analyze the following:

- o Natural frequencies of the primary structure constrained in the launch configuration for both the Delta vehicle and the STS
- o Buckling modes of critical structural members
- o Frequency response of the structure to frequency-dependent input loads defined for both launch environments, the reentry environments, and significant orbit operations
- o Coupled-modal response of the Instrument Module and the MMS
- o Frequency response of the structure to frequency-dependent input loads defined for the qualification test of the instrument module mounted to a vibration-test machine

- o Modal analysis of the Flight Segment in its orbit configuration for analysis of MMS control system performance or structural interaction

6.3.6

Structural/Electro-Optical Performance Analysis. The Landsat-D Project Office may direct that a structural/electro-optical performance analysis be performed on electro-optical system(s) which form part of the Flight Segment. This analysis shall evaluate the ability of the electro-optical system to perform within the allowable error budgeted for that system when acted upon by thermal and mechanical environmental loads.

6.3.7

Execution Phase. The structural analysis shall be maintained throughout the execution phase of the Flight Segment program as an accurate representation of the equipment by reflecting modifications in the structure, knowledge of the environment, or mission requirements. The static, dynamic, and structural/electro-optical analyses shall be confirmed and updated on the basis of test results as appropriate.

6.3.8

Acoustic Analyses. Acoustic analyses shall be performed to substantiate the design and to establish that the subsystems and Flight Segment will perform satisfactorily when subjected to the acoustic environment as specified in Appendix A of the document described in Paragraph 2.1.6.1.

6.3.9

Electronic Analyses. Worst case electronic analyses shall be performed to establish the performance of all electric and electronic circuits. These analyses shall establish performance criteria such as gain stability, noise immunity, etc. These analyses shall address all factors pertinent to the success of the circuits such as environment extremes, operating factors for components, etc. Diagrams shall be made to describe the functional and timing relationships of all subsystems. Requirements shall be established for decoupling to ensure proper stability and control of system parameters such as gain, crosstalk, noise immunity, linearity, and dynamic range.

- 6.3.10 Failure Mode Effects Analyses. Failure mode effects analyses shall be performed in accordance with Paragraph 1A303 of the document specified in Paragraph 2.2.1.2.
- 6.3.11 Error Analyses. Error analyses shall be performed to substantiate that the design meets the requirements of this document.
- 6.3.12 Pointing System Analyses. Pointing system analyses and trade-off studies shall be performed to help in the design of the pointing system. The analyses shall substantiate that the pointing system meets the pointing requirements of this document specified in Paragraph 3.2.4.2.1.6.
- 6.3.13 Flight Segment Mission Power Profile Analyses. Flight Segment mission power profile analyses and trade-off studies shall be carried out to verify the choice of the MMS power module options and the design of the instrument module power subsystems (including choice of solar array size.) These analyses must substantiate the ability of the power system design to meet the load requirements of Paragraph 3.1 for a minimum lifetime of three years and the requirements of Paragraphs 3.2.3.3 and 3.2.4.3.4.
- 6.3.14 Antenna Positioning. An antenna pointing system analysis and trade-off studies shall be provided to aid in the design of the high gain antenna pointing system.
- 6.3.15 RF Link Analyses. An RF link analysis shall be made for each communication link. These analyses shall address all factors of the communication system such as rain and cloud conditions, seasonal variations, spacecraft equipment parameters, ground equipment parameters, and system margins.

6.4

FLIGHT ASSURANCE DOCUMENTATION

The Flight Assurance documentation shall be prepared in accordance with Paragraphs 2.2.1.6, 4.0 and Section 4.7.

6.5

MANUALS, HANDBOOKS, AND LISTS

Manuals shall contain information, as appropriate, regarding the use, operation, calibration, maintenance, and handling of the Landsat-D systems. Manual and handbook format shall conform to the requirements of the document specified in Paragraph 2.2.1.8, as applicable. As appropriate, these documents may be combined. The manuals required are:

- o Flight Segment Operations Manual - delineates normal procedures, fault diagnosis, and redundant modes of operation.
- o Ground Segment Hardware Operations and Maintenance Manuals- delineate normal contingency, and emergency operating procedures, and procedures for repair, troubleshooting, and remedial actions.
- o Documentation Reference Manual
- o Ground Segment Overview and System Operations and maintenance Manuals. Describes system hardware and software, interconnections of systems, and system operation.

- o Ground Segment Software Maintenance Manuals.
- delineate all software development for Ground Segment operations.
- o Data Format Control Book - delineates system data formats for all Flight Segment transmissions and Ground Segment user products.
- o Ground Support Equipment Instruction Manual - describes GSE facilities, interfaces, operation, and repair.
- o Flight Segment Systems Restraints Manual (Operations and Test) - describes any special handling and/or operational, functional, or environmental, etc. restraints that must be observed to prevent any degradation or damage to any part of the Flight Segment.
- o Landsat Data Users Handbook - to satisfy investigators' and users' needs for information about Landsat data products and how to acquire them.
- o Landsat Data Users Handbook inputs- Support DOI/EDC in publishing a Landsat Data Users Handbook to satisfy investigators' and users' needs for information about Landsat data products and how to operate them.

Individual lists shall be prepared for the OCC, LAS, TGS, and DMS with appropriate cross-references to drawings, schematics, etc. List format shall be proposed by the contractor.

- o Flight Segment Command and Telemetry List
- o Configured Articles List
- o World Reference System Frame Center Lists

6.6

DRAWINGS

The contractor shall provide aperture cards of all assembly and subassembly drawings, schematics, interface drawings, and contractor-prepared specifications with complete indexing and cross-referencing.

Photographs at significant milestone points in the system development shall be prepared in accordance with the requirements of the document specified in Paragraph 2.2.1.7.

6.7

DESIGN REVIEW PACKAGES

A design review package shall precede the GSFC Project Reviews, the Conceptual and Detailed Design Reviews for each deliverable portion of the Flight Segment, Ground Segment, the Pre-Environmental Review and the Pre-Launch Review for the Flight Segment, and a Flight Operations Review for the entire Landsat-D System, and be in accordance with Paragraph 4.2.1. The data packages shall include but not be limited to the following as applicable to system or subsystem under review:

Contents of Design Review Data Packages:

- o Performance Specifications (system performance specifications for Detailed Design Reviews)
- o GSE Design Specification
- o Engineering Analyses
- o Integrated Test Plan
- o Reliability Analyses
- o Systems Analyses
- o Failure Mode Effects Analysis and Updates (updates only required for reviews after the Conceptual Design Review for each reviewed item)
- o Parts and Materials Lists and Updates (updates only required for reviews after the Conceptual Design Review for each review item)

- o Protoflight (Flight Acceptance) Test Plan
- o Configured Articles List

6.8

REPORTS

A number of reports are required to substantiate the progress and detail the performance of the systems. These reports include:

- 6.8.1 Technical Progress Reports. Technical progress reports shall be submitted as delineated below as specified in Paragraph 2.2.1.6. Three types of reports are required:
 - 6.8.1.1 Weekly Report. This report shall be submitted each week and transmitted to GSFC by way of "Wire-fax" machines. The purpose of this report is to allow GSFC to be kept closely aware of major developments in carrying out the contract. The information in this report shall be very concise with liberal use of work breakdown structure nomenclature to describe the topics addressed in the report. The report shall address, but not be limited to, the following topics:
 - o Current action items
 - o Progress in resolving action items since last report
 - o Identification of other problem areas and potential problem areas
 - o Major personnel changes
 - o Schedule status
 - o Funding status.
 - 6.8.1.2 Type I Report. This is a monthly report as specified in Paragraph 3.1 of the above referenced specification. This report shall also contain the latest Flight Segment power and weight status.
 - 6.8.1.3 Type III Report. This is a final report as specified in Paragraph 3.3 of the above referenced specification.

6.8.2 Test Reports. Test reports shall be prepared for each of the following categories,

6.8.2.1 Flight Segment Test Reports. These reports shall be in accordance with Paragraph 1A402 of the document specified in Paragraph 2.2.1.2 and Paragraph 3.2.6.

- o Protoflight Test Report
- o Flight Acceptance Test Report
- o Design Qualifications Test Report(s)

6.8.2.2 Ground Segment Test Reports. These reports shall include:

- o Prelaunch Acceptance Test Report
- o Operational Readiness Test Report
- o Final Acceptance Report

6.8.3 End-Item Data Package. At the time of delivery of hardware an end-item data package shall be supplied. This package shall be in accordance with Paragraph 2.2.1.6 and shall include copies of the following:

- (1) Protoflight Model (PFM) and Flight Model (FM)
 - o Final Flight Segment Performance Specification
 - o Complete Set of Aperture Cards
 - o Equipment Logs
 - o Malfunction Reports Summary List
 - o Failure Reports, Analysis, and Corrective Action Reports
 - o Parts and Material Lists
 - o Bench Acceptance Test Procedures
 - o Handling, Receiving, and Inspection Procedures
 - o System Safety Plan
 - o Data Measurements List

- o Spare Parts List
- o Instruction Manual
- o Flight Acceptance Test Report (FM only)
- o Configured Articles List (CAL) (Verified)
- o Qualification Test Report (PFM only)
- o Calibration Report.

(2) Ground Segment (GS)

- o Final Ground Segment Performance Specifications
- o Complete Set of Aperture Cards
- o Equipment Logs
- o Malfunction Reports Summary List
- o Failure Reports, Analysis, and Corrective Action Reports
- o Parts and Material Lists
- o Handling, Receiving, and Inspection Procedures
- o System Safety Plan
- o Spare Parts List
- o Final Acceptance Test Reports (one each for the four GS delivery phases)
- o Configured Articles Lists (CAL) (Verified)
- o At the time of software delivery, associated unit development folders shall be supplied

6.8.4

Final Report. The final report shall document the results of the entire work performed to meet the requirements of this specification.

APPENDIX A

LANDSAT-D TRANSPORTABLE GROUND SYSTEM

A.1 TRANSPORTABLE LANDSAT-D GROUND SYSTEM

The Transportable Landsat-D Ground System consists of a transportable 9-meter (minimum) antenna and receiver system which will be used to receive Landsat-D signals on X-band and S-band. The antenna subsystem shall consist of a mount which provides hemispherical coverage. A 9 meter (minimum) diameter parabolic reflector with both S-band and X-band receive only capability shall be provided. A servo-drive system that provides for manual operation, for a programmed mode, for a slew mode, and for an autotrack capability on both frequency bands shall be provided. This system will interface with the DMS/OCC in the same manner as described for the NTTF STDN facility (see Figure 3.3.2.1-1). Commercial power shall be provided for this system.

A.2 TRANSPORTABILITY

The Landsat-D Transportable Ground System shall be capable of being air transported in the C-141 cargo aircraft and by standard ground transportation modes.

A.3 INSTALLATION

Installation of the ground station, after the station site has been surveyed and all preparations made, shall be accomplished in 20 working days. The system should be capable of being installed by normal maintenance and operations crews without the use of any special heavy equipment. The station shall be capable of disassembly and relocation a minimum of five times within a period of 5 years without major overhaul, modifications, or performance degradation. Crane services, for the initial installation at GSFC, are to be provided by the contractor.

A.4 PACKAGING

The contractor shall install antenna control, receivers, simulators, etc., in a transportable van or trailer. The mobile vehicle shall be between 30 feet and 40 feet in length and shall have an interior height of 77 inches. The vehicle shall be equipped with an air ride type suspension system and the weight shall be distributed so that tire loading is approximately equal. The vehicle shall be capable of being towed by a standard air suspension commercial 5 ton 4 x 2 tractor.

A.5 ANTENNA SUBSYSTEM

The contractor shall install and check out the antenna subsystem at a TBD site at the GSFC. The antenna subsystem shall consist of a mount that provides coverage from 0 degrees to 180 degrees in elevation and at least 500 degrees in azimuth without unwrapping. A 9 meter (minimum) parabolic reflector with feeds at both X-band and S-band which have the capability of autotracking and receiving TM, MSS, and housekeeping data from Landsat-D shall be provided.

A.5.1 X-Band RF Antenna Characteristics

Frequency Band - 8.025 to 8.4 GHz.

Gain (G) - Determined by system design

Polarization - RHC.

System Noise Temperature (T)-Determined by system design. G/T-+30.8 db/°K minimum (including receiver; at 5° elevation with no precipitation).

Null Depth - The depth of the central null in each tracking feed error channel shall be at least 35 dB below the maximum. The position of the central null of either error pattern shall not shift more than 3% of the related sum channel beamwidth for any orientation or polarization of an incoming linearly polarized wave.

Crosstalk - Crosstalk between the two orthogonal channels of the feed shall be no greater than 10% over $\pm 25\%$ of the sum channel beamwidth.

A.5.2 S-Band RF Antenna Characteristics

Frequency Band - 2200 to 2300 MHz.

Gain (G) - Determined by system design.

System Noise Temperature (T) - Determined by system design.

G/T - +20.8 db/°K minimum (at 5° elevation, including receiver).

Polarization - RHC

Null Depth - The depth of the central null in each tracking feed error channel shall be at least 35 dB below the maximum. The position of the central null of either error pattern shall not shift more than 3% of the related

sum channel beamwidth for any orientation or polarization of an incoming linearly polarized wave.

Crosstalk - Crosstalk between the two orthogonal channels of the feed shall be no greater than 10% over $\pm 25\%$ of the sum channel beamwidth.

A.5.3

Operational Modes

The antenna subsystem shall be operated in the following modes:

1. Manual
2. Slew
3. Program
4. Autotrack

A.5.3.1

Manual Mode. The manual positioning mode shall enable the operator to accurately position the antenna. Readout indications of true antenna position in both axes shall be to an accuracy of ± 0.010 degrees. The resolution of the controls shall allow the positioning of the antenna to within ± 0.020 degrees of any position as indicated on the readout under zero wind conditions. The antenna drive system shall be able to drive the antenna to stow position in winds of 60 mph, and it shall be capable of driving the antenna at 2 deg/sec in mean winds of 30 mph. The minimum acceleration capability shall be 1 deg/sec². Limiters shall be incorporated within the manual drive system to prevent inadvertent excess of velocity and accelerations.

A.5.3.2

Slew Mode. The slew mode shall enable smooth rapid positioning of the antenna in both axes in all directions. Means shall be provided to limit the acceleration and deceleration of the antenna to a safe value when switching from the various modes. Slew mode acceleration capability shall be 1 deg/sec² in both axes.

A.5.3.3

Program Mode. A program track mode for this antenna shall be supplied. Inter Range Vectors (IRV) will be provided from GSFC. The antenna programmer will consist of the necessary hardware such as computer, encoder, etc., to convert these IRV to position pointing information. Direct computer control or drive tape control is acceptable. The IRV format shall be supplied at a later date.

A.5.4 Pedestal and Foundations

A.5.4.1 Balance. The antenna and counterweights shall be balanced about the pedestal's elevation axis to within 300 ft.-lb. Any residual unbalance shall be due to excess counterweights. The system shall be damped such that these are no more than two overshoots - settling time shall not exceed 1.5 sec (within 5% of final value).

A.5.4.2 Stow Pins. Each axis shall have a single remote-operated stow pin for stowing at zenith position. An indicator showing position of the stow pin shall be provided.

A.5.4.3 Limit Switches. Switches shall be used to prevent damage when approaching the mechanical limits of operation. Mechanical snubbing devices shall be used to prevent mechanical contact of a damaging nature.

A.5.4.4 Foundations. Foundation design criteria shall be furnished to NASA. Foundations will be constructed by NASA.

A.5.5 Safety Provisions

Appropriate safety devices such as limit switches, stop buttons, audio warning devices, etc., shall be provided on the antenna mount and service area. Guard rails at maintenance platforms shall also be provided.

A.5.6 Environmental Conditions

A.5.6.1 Temperature Limits.

1. Operating - -25°F to $+135^{\circ}\text{F}$
2. Nonoperating - -35°F to $+135^{\circ}\text{F}$
3. Transport - -25°F to $+135^{\circ}\text{F}$

A.5.6.2 Humidity. Any relative humidity up to 100%.

A.5.6.3 Wind Conditions.

1. Operation within specifications - 45 MPH
2. Impaired signal operations - 55 MPH
3. Drive to stow position - 60 MPH
4. Strength of structure (reflector in any position) - 70 MPH

5. Strength of structure (structure stowed in zenith position) - 120 MPH

A.5.6.4 Ice. The antenna shall be designed and constructed to withstand a one-inch radial ice load in conjunction with a 60 MPH wind load while in the stowed position.

A.5.6.5 Snow. The antenna shall be able to withstand, without permanent deformation, a 24-inch load of snow (8 pounds/cu ft) while in the stowed position.

A.5.7 Special Antenna Test Devices

A.5.7.1 Contour Checking. The procedure used to check the contour of the parabolic reflector after its initial assembly shall be provided. The measurements made using the procedure and the computed contour data shall be provided.

A.5.7.2 Antenna Parameter Measurements. Equipment shall be supplied for measuring antenna gain and checking the antenna patterns.

A.5.7.3 Alignment Scope. An optical alignment scope and mount shall be provided for establishing azimuth axis reference.

A.6 SYSTEM TRACKING AND POINTING ACCURACY

The automatic tracking system shall maintain the pointing direction of the electrical axis of the antenna relative to the true pointing direction of a satellite transmission with an error not to exceed the following values:

<u>Allowable Error</u>	<u>Mean Wind</u>	<u>Peak Wind (Including Gusts)</u>
.056 Degrees	0 to 30 MPH	Up to 45 MPH
.084 Degrees	31 to 45 MPH	Up to 60 MPH

Wind gusts shall be defined as having a rise time of one second and shall generate peak wind velocities equal to the sum of the mean wind and gust values. Angular errors refer to space pointing vector. The design shall be based on a target having a maximum velocity of 2 degrees/second and a maximum acceleration of 1.0 degrees/second².

A.7 RECEIVER SUBSYSTEM

The receiver subsystem shall consist of an X-band and S-band receiver that have the capability of demodulating the spacecraft data modes defined in Table 3.2.4.3.1.3-1 and the housekeeping modes which are transmitted to the ground.

A.7.1

X-Band Receiver Subsystem

The X-band receiver subsystem shall be capable of receiving and demodulating all X-band communication modes. This subsystem shall support a TM link of 10^{-6} BER and a MSS link of 10^{-5} BER. The X-band receiver shall consist of the following components:

- a. Test Injection Network
- b. Parametric Amplifier
- c. Down Converter
- d. Signal Distribution Amplifier
- e. Data Receiver/Demodulation
- f. Autotrack Receiver
- g. QPSK Simulator
- h. Collimation Equipment
- i. Feed filter with a nominal bandwidth of 500 MHz (-1 db) about center frequency and a form factor of 5:1 minimum (-50 db to -1 db).

A.7.1.1

Test Injection Network. A test injection network shall be incorporated at the input of each parametric amplifier. This network will consist of power dividers and directional couplers which will be used to inject test signals into each receiver channel without breaking the signal path.

A.7.1.2

X-Band Parametric Amplifier. An X-band parametric amplifier shall be mounted on the antenna structure. The number of channels shall be determined by the autotrack system proposed. This system is required to receive data and track only in a right circular polarization mode. The parametric amplifier shall have the following characteristics:

A.7.1.2.1

Center Frequency 8.2125 GHz.

A.7.1.2.2

Frequency Band 8.025 to 8.4 GHz.

A.7.1.2.3

RF Bandwidth Determined by spacecraft modulation parameters.

A.7.1.2.4

Noise Temperature 70°K maximum.

A.7.1.2.5 Gain Determined by system noise temperature requirements.

A.7.1.2.6 Type Noncooled.

A.7.1.3 Down Converter. The down converter shall provide a fixed frequency translation of the X-band signal down to an Intermediate Frequency (IF) to be selected by the contractor. The down converter shall be located on the antenna structure. The RF bandwidth shall be determined by the design of the spacecraft X-band communication system. Gain will be determined by system noise temperature requirements.

A.7.1.4 Signal Distribution Amplifier. The signal distribution system shall provide separate isolated outputs to drive two redundant data receiver/ demodulators. The gain and bandwidth parameters will be determined by the system design.

A.7.1.5 Data Receiver/Demodulator. The X-band receiver/ demodulator will consist of frequency selection circuitry, a PSK/QPSK demodulator, bit synchronizer/signal conditioners, and any additional circuitry necessary to demodulate any X-band mode and provide both an 84 MBPS and a 15 MBPS data stream. Redundant receiver/ demodulators shall be supplied. The input will be from the signal distribution amplifier.

The receiver/demodulator shall include amplifiers, filters, and automatic gain control, etc., to achieve the required bit error rate performance. The IF output to the receiver/ demodulator shall include a phase lock loop for tracking the Doppler frequency and to minimize or average out any static phase error due to tracking dynamics. The carrier reference needed to demodulate the quadriphase signal to baseband will be generated by means of a phase lock loop controlling a voltage control oscillator. The demodulator shall employ a Costas type phase lock loop for Doppler tracking, carrier regeneration and synchronization. The demodulator will contain bit synchronizers and signal conditioners for both the I and Q channels. Differential decoders and PN decoders shall also be supplied if the system design dictates these features. The demodulator shall be capable of handling PSK or QPSK modulation.

A.7.1.5.1 Receiver/Demodulator Parameters

A.7.1.5.1.1 Input Frequency Variation The input frequency variation will be determined by the Doppler associated with the Landsat-D orbit.

- A.7.1.5.1.2 Automatic Gain Control (AGC) The AGC system shall be included in the design to assure that the signal at the "I" and "Q" detectors shall be held constant over the dynamic range of the system even when the phase lock loop has 1 radian RMS phase noise.
- A.7.1.5.1.3 False Lock Prevention The demodulator shall include features to avoid false locks.
- A.7.1.5.1.4 Tracking Accuracy The phase lock loop shall track all input signals varying linearly in frequency without exceeding a steady state phase error of 0.1 radians.
- A.7.1.5.1.5 Demodulator Performance The receiver demodulator shall be required to support a bit error rate performance that is 2.5 dB of theoretical for bit error rates of 10^{-2} to 10^{-6} .
- A.7.1.5.1.6 Acquisition Time With a ± 2 percent offset of the incoming bit rate the system shall acquire within one hundred milliseconds. The bit synchronizer and signal conditioner (BSSC) shall reacquire with an E_b/N_0 of at least 7 dB.
- A.7.1.5.1.7 VCO Drift In the absence of the input data signal the VCO shall not drift more than ± 5 percent of its center bit rate.
- A.7.1.5.1.8 Tracking The system shall track the incoming bit rate within $\pm 10\%$ of the pre-set center frequency down to a 10^{-3} error rate.
- A.7.1.5.1.9 Bit Slippage Bit slippage shall not exceed 10^{-7} over the specified performance range.
- A.7.1.5.1.10 BSSC Outputs Line driver amplifiers shall be provided for the conditioned data and the clock for driving low impedance coaxial cables. These line drivers shall be ECL compatible and shall be capable of driving 50 feet of coaxial cable terminated into 50 ohms.
- A.7.1.6 Autotrack Receiver. A cross correlation autotrack receiver that will be used to track the X-band signal and provide error signals for steering the 9 meter antenna shall be provided. Selectable bandwidths will be included in the design to provide the capability of tracking the different data rates as defined by the spacecraft wideband modes.

A.7.1.7 QPSK Simulator. An X-band simulator that produces simulated Landsat-D wideband signals shall be provided. This simulator shall operate at a fixed X-band frequency of 8.2125 GHz. The simulator shall consist of power output attenuators, RF amplifiers, PSK/QPSK modulators, frequency generator and translators, data generators and a bit error detector.

The RF power output and attenuator will be designed to be able to test the receiver system including the parametric amplifier over the total dynamic range of the system. The PSK/QPSK modulators shall be capable of handling all the wideband data modes transmitted at X-band. The data generator shall provide two independent data patterns in order to simulate the mode where both MSS and TM are on the X-band carrier. The data output shall be a Pseudo-Random Binary Sequence (PRBS) either in an NRZ or split phase format. Switching shall be provided to select transition densities of 25 percent or 50 percent and duty factors as low as 10 percent and as high as 90 percent.

A bit error detector shall be provided capable of generating PRBS identical to that generated by the data generator. The two sequences shall be compared bit-by-bit and an error pulse generated when the two sequences are not identical. A counter and display shall be provided to count bit error rate.

A.7.1.8 Collimation Equipment. A four foot diameter maximum antenna and signal source shall be provided for use in phasing the autotrack portion of the X-band receiver. An existing erected collimation tower (150 feet up-right) will be provided (GFE) at the GSFC prepared site. A CW source at the X-band frequency with variable power level capability shall be provided. The collimation antenna should have the capability of being rotated 360 degrees.

A.7.1.9 Outputs and Monitoring.

A.7.1.9.1 AGC Outputs An analog AGC output shall be provided on a coaxial connector.

A.7.1.9.2 AGC Meter A front panel meter shall display AGC levels calibrated in dbm referenced to the parametric amplifier input.

A.7.1.9.3 Antenna Error Meters A meter shall be provided for each antenna axis showing the error voltage derived from the autotrack receiver.

A.7.2

S-Band Receiver Subsystem

The S-band receiver shall provide the capability to demodulate the MSS data on the 2265.5 MHz link, demodulate the housekeeping and computer dump data on the 2287.5 MHz STDN link, and autotrack on either frequency. The S-band receiver subsystem shall consist of the following elements:

- a. Test Injection Network
- b. Parametric Amplifier/Preamplifier
- c. Down Converter
- d. Signal Distribution Amplifier
- e. Receiver/Demodulator
- f. Autotrack Receiver
- g. Bit Synchronizer/Signal Conditioners
- h. S-Band Simulator
- i. PSK Subcarrier Demodulator
- j. Feed filter with a nominal bandwidth of 100 MHz (-1 db) about the center frequency (2250 MHz) and a form factor of 5:1 minimum (-50 db to -1 db).

A.7.2.1

Test Injection Network. This network will consist of directional couplers and power dividers which will be used to inject test signals at the input of each parametric amplifier or low noise preamplifier channel. This signal injection will be accomplished without breaking the signal path.

A.7.2.2

Parametric Amplifier/Preamplifier. A noncooled single channel parametric amplifier shall be provided for the data channel. If the autotrack design requires additional channels, transistorized low noise preamplifiers may be used. The parametric amplifier shall have the following parameters:

Bandwidth - 100 MHz (1 db points)

Center Frequency - 2250 MHz

Noise Temperature - 50°K maximum

Gain - TBD by system noise temperature requirements

Dynamic Range - Thermal noise to -50 dbm.

- A.7.2.3 Down Converter. A fixed frequency down converter shall convert the 2200 to 2300 MHz band to an Intermediate Frequency (IF). The IF shall be determined by the contractor. The 1 db bandwidth of the converter shall be 100 MHz. Noise figure and gain will be determined by the system design required to meet the overall system noise temperature.
- A.7.2.4 Signal Distribution Amplifier. A signal distribution amplifier shall be provided at the IF frequency. This unit shall have the capability of driving at least four data receivers in addition to any autotrack receiver interface requirements. Two data receivers and one autotrack receiver shall be provided as part of this procurement.
- A.7.2.5 Receiver/Demodulation/Autotrack (2265.5 MHz Link). Two receiver demodulators shall be supplied. Each receiver shall have the capability of demodulating the MSS link at 2265.5 MHz. Each receiver shall have the capability of an autotrack receiver to non-coherently track the MSS 2265.5 MHz link. Each receiver shall be useable in either the data demodulation mode or the autotrack mode. The receivers will include an FM demodulator for MSS data with the following characteristics:
- A.7.2.5.1 FM Demodulator This demodulator shall demodulate the 2265.5 MHz carrier to baseband.
- A.7.2.5.1.1 Demodulation Linearity The total harmonic distortion of the demodulated signal shall be less than 2 percent for a modulating rate 10 percent of the IF bandwidth and a peak deviation equal to 25 percent of the IF bandwidth.
- A.7.2.5.2 Video Output The receiver shall be capable of producing at least 1.0 volt RMS into a 50 ohm load at the end of 200 feet of coaxial cable. A front panel control shall be provided for setting this level.
- A.7.2.5.3 AC and DC Outputs Both AC and DC coupled outputs shall be provided. The AC coupled output shall have a low frequency response of 2 Hz at 3 db point.
- A.7.2.5.4 IF Bandwidths For MSS data the 1 db bandwidth shall be 15 MHz. This filter shall have a group delay variation of less than 10 nanoseconds over 80% of the bandwidth and of less than 20 nanoseconds over the full bandwidth. The group delay shall be symmetrical about center frequency.

- A.7.2.6 Receiver/Demodulation/Autotrack (2287.5 MHz Link). Two receiver demodulators shall be supplied. Each shall have the capability of demodulating the housekeeping telemetry link at 2287.5 MHz. Each receiver shall have the capability of an autotrack receiver to coherently track the 2287.5 MHz link. Each receiver shall be useable in either the data demodulation mode or the autotrack mode. These receivers shall have the capability of tuning to any frequency in the 100 MHz IF bandwidth. This selection may be made by the selection of a crystal although a minimum of five switch selectable positions shall be provided. A wide deviation VCO shall provide at least ± 150 KHz tracking capability around center frequency. The receivers will include a synchronous phase demodulator with the following characteristics:
- A.7.2.6.1 Synchronous Phase Demodulator Provide a synchronous phase demodulation with sinusoidal transfer characteristics for the real-time housekeeping subcarrier and the 32 kbps computer dump data.
- A.7.2.6.1.1 Linearity With an input signal sine wave modulated ± 1 radian, the total harmonic content of the demodulated signal measured at a video output level of 1.0 volt RMS at 50 ohms shall be less than 5.5 percent.
- A.7.2.6.2 Video Output The receiver shall be capable of producing at least 1.0 volt RMS into a 50 ohm load at the end of 200 feet of coaxial cable. A front panel control shall be provided for setting this level.
- A.7.2.6.3 AC and DC Outputs Both AC and DC coupled outputs shall be provided. The AC coupled output shall have a low frequency response of 2 Hz at 3 db point.
- A.7.2.6.4 IF Bandwidths For the real-time or computer dump data the 1db bandwidth shall be 3.3 MHz. This filter will have a ratio of 1.7:1. or less, for the 3db bandwidth to 1db bandwidth. This filter shall have a form factor of 3.5 ± 0.5 (50db to 1db).
- A.7.2.7 Bit Synchronizer and Signal Conditioner (BSSC). Redundant BSSC's shall be provided for the housekeeping real-time telemetry and computer dump data. Redundant BSSC's shall be provided for the MSS data. These signal conditioners shall perform to within 2.5 db of theoretical for bit error rates of 10^{-2} to 10^{-6} .
- A.7.2.8 S-Band Simulator. An S-band simulator which can simulate the real-time telemetry, computer dump and MSS links shall be provided. This simulator shall operate at either 2265.5 MHz and 2287.5 MHz.

An FM modulator shall be provided for MSS data and a PM carrier modulator for the telemetry link. A PSK subcarrier modulator shall also be included. A data generator with the capacity of simulating any of the three types of data shall be provided. A bit error detector which can generate identical patterns and do a bit-by-bit comparison shall be included. A counter and display will provide a visual indication of bit error rate.

A.7.2.9 PSK Demodulator. A PSK subcarrier demodulator capable of demodulating the real-time housekeeping telemetry shall be provided.

A.7.3 Timing System

A timing signal receiver and antenna shall be provided. The frequency coverage shall be 2 to 30 MHz. A time code generator and time code display giving GMT to the second shall be provided. The time code generator shall have the capability to synchronize to the timing signal from the timing signal receiver and to a serial modulated 1 KHz NASA 36 bit timing signal. The time code generator shall provide three serial outputs. Each output shall be IRIG A serial time code modulated on a 10 KHz carrier at a level of 2.8v peak-to-peak into a 600 ohm load. A rechargeable battery pack shall be provided for the time code generator to maintain the time base for a period of 48 hours without external power.

A.7.4 Test Equipment

Test equipment for the maintenance and repair of the antenna and receiver subsystems shall be provided. This equipment shall include but not be limited to the following items:

- a. Spectrum analyzer
- b. Sand X-band signal generators
- c. Oscilloscopes
- d. Frequency counters
- e. RF sweep generator
- f. RF power meters
- g. Digital voltmeters
- h. Loads and terminations

- i. Noise figure measurement systems
- j. Vector voltmeters
- k. Multimeter

A:7.5

S-band Collimation System

An antenna and CW source shall be provided for use with the tower called out under the X-band receiver. The antenna shall have the capability of being rotated. The antenna shall be four foot diameter maximum.

A.8 RECORDER INTERFACE SUBSYSTEM

A Recorder Interface Subsystem shall be provided for the simultaneous transmission of TM and MSS data to the DMS Recording Facility from the Bit Synchronizers and Signal Conditioners (BSSC) in the TGS Van. The signal interface at the DMS Recording Facility shall be in accordance with EIA RS-422 (See Paragraph 2.2.1.15 of this document). The mechanical and electrical interface shall be compatible with the recorders in the DMS Recording Facility. The distance from the TGS Van to the DMS Recording Facility will be less than 2000 feet. A similar interface for TM and MSS data shall be provided in the TGS Van. The increase in bit error rate of the TM and MSS data after transmission through the Recorder Interface Subsystem shall not exceed 1×10^{-7} . A bit error detector shall be provided at the DMS Recording Facility to measure and display the bit error rate of data generated by the QPSK simulator and transmitted thru the TGS system to the DMS Recording Facility.